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Theme Overview: Modern Challenges and Resilience Strategies in the US Dairy Industry

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JEL Classifications: Q12, Q13, Q16, Q18
Keywords: Automation, Beef-on-dairy, Dairy economics, Genomic testing, Sustainability

The dairy industry generates about 3.4% of US GDP annually, equivalent to $794 billion in 2024. However, it is facing multiple challenges including labor shortages, disease outbreaks, concerns on its environmental footprint, variable milk-feed margins and farm closures. Our theme explores multiple resilient strategies implemented by US dairies to overcome these obstacles, such as automation, biosecurity measures to combat the avian flu, sustainable practices, genomic testing, and beef-on-dairy breeding. In addition, the theme also discusses the updates to milk prices, which took effect in June 2025.

In the first paper, Peña-Lévano et al. examine the increasing role of automation in dairy farming, particularly in California and Wisconsin, where labor shortages and rising wages pressure farmers toward new technologies. Automated milking systems (AMS) are viewed as a possible solution to lessen reliance on labor, but high upfront costs and necessary infrastructure upgrades impede widespread adoption. Variations between the states underscore labor challenges—California's larger farms rely more on immigrant labor, whereas Wisconsin's dairy operations struggle to find temporary workers. In addition to AMS, farmers are progressively adopting ancillary technologies such as automatic feeders and manure management systems to enhance efficiency and address labor shortages.

The second paper, presented by Garcia-Covarrubias et al., discusses the 2024–2025 avian influenza A(H5N1) outbreak in US dairy cattle. The first known case of transmission was initially detected in Texas, spreading rapidly to 16 states, raising significant economic and health concerns. Farmers reported respiratory issues and decreased milk production, leading to public alarm. Although pasteurization neutralizes the virus, the outbreak prompted stricter biosecurity measures and government support to mitigate financial impacts.

Articles in this Theme:

Burney et al. investigate sustainable practices among Wisconsin dairy farmers, emphasizing the complex interplay between economic, demographic, and sociological factors. Farm profitability emerges as a crucial factor for sustainability, with an increasing number of dairy operations investing in environmentally friendly practices. Key findings show that smaller farms favor grazing and organic production, while larger farms are more inclined toward practices like no-till and nutrient management.

Hutchins and Funes Leal examine the impact of genomic testing on milk yield in the US dairy industry. Despite advances since adopting genomically tested bulls in 2010, average national yields have not reflected the predicted improvements. Factors such as herd size, farm management practices, and environmental conditions influence the gap between genetic potential and actual production. Further research is needed to bridge this gap and maximize the benefits of genetic advancements.

The fifth article, by Pinto et al., explores the growing use of beef-on-dairy breeding in US dairy farms to generate an additional source of income. In this study, the researchers present an economic model that evaluates the financial viability of crossbreeding in typical dairy operations. Key findings highlight the importance of the herd lactation cycle, use of sexed semen and the period between lactation on the profitability of crossbreeding.

Finally, Nicholson, Wolf, and Stephenson explore the USDA's recommended decision to update milk pricing regulations under the Federal Milk Marketing Orders (FMMOs), the most significant changes in over 2 decades. These updates took effect in June 2025 and include adjustments to milk composition factors to reflect modern dairy production. These updates aim to better align pricing with industry realities and improve market stability but will have mixed regional impacts.

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Labor Constraints and Automation Trends in California and Wisconsin Dairy Farming

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What Motivates This Article

The dairy industry is a cornerstone of US agriculture, particularly in California and Wisconsin—the two largest dairy-producing states. Both states jointly produce a third of the nation's milk and employ about 35,000 farmworkers (Jette-Nantel, 2018; Matthews and Sumner, 2019). However, dairies in both states face labor shortages, rising wages, and difficulties in retaining and managing workers—issues that worsened during the COVID-19 pandemic and have continued since (Peña-Lévano, Burney, and Adams, 2020; Liebrand, 2022). In response, dairy farmers are exploring automation in dairy activities to decrease labor reliance (Peña-Lévano, Burney, and Beaudry, 2023). In this article, we examine the findings of a large-scale survey conducted in 2024 aimed at assessing the perceptions of dairy farmers in California and Wisconsin regarding labor challenges and automation, with emphasis on robotic milking. The study reveals significant regional differences in labor sources as well as the key barriers and drivers for adopting automated milking systems (AMS), offering valuable insights into the future of the dairy industry.

Automated Milking Systems (AMS) as an Alternative to Decrease Reliance on Manual Labor

Multiple processes within dairy operations can be automated. However, while AMS are gaining attention as a technology that can be used to decrease the reliance of manual labor, they require a large up-front investment and often modification of the barn infrastructure and changes in farm management (Peña-Lévano et al., 2025).

AMS are robots with a hydraulic arm, lasers, and cameras that allow the teat cups to autonomously attach to the cows' udder for a hands-free milking operation. Overall, each robot box can milk 60–70 cows per day (Peña-Lévano et al., 2025). AMS systems are available in two configurations: (1) linear, where cows approach the robot at their own pace, and (2) rotary systems, in which dairy cows are guided by workers into the rotating milking parlor (Siewert, 2017; Marques et al., 2023). The leading linear AMS technologies in the US are DeLaval's VMS robots and Lely's Astronaut, with emergent competition from GEA's R9500, Boumatic's Gemini and Galaxy USA's Merlin (Marques et al., 2023; Peña-Lévano, Burney, and Beaudry, 2023). Linear AMS parlors may require new barn construction or retrofitting an existing barn. New barns are designed either in a free-flow, where cows move freely throughout the barn, or a guided-flow setup that uses gates and barriers to direct the cows to the robots (Marques et al., 2023).

Figure 1 explains the milking process in a free-flow linear robotic setup. Each animal has a unique identifier that allows the AMS to measure close to 100 different parameters and track a wide range of individual cow data (such as milk yield, somatic cell count, health metrics, milking frequency, activity levels, rumination patterns, and feed intake). Once a cow enters the robot, it is identified using its collar, and the system determines whether to accept or reject the cow based on milking permission settings. Once a cow is inside the robot, the first step is udder identification, where sensors and cameras locate the teats. After identifying their position, the prepping process begins, with automated brushes or cleaning cups disinfecting and cleaning the teats. To encourage visits to the robot, farms offer feed, though the type varies: some provide pellets, others a meal. Once the cow is prepped, the system attaches milking cups to each teat, and the milking process begins. After milking, the system applies a teat disinfectant to prevent infections. Finally, the gate opens, allowing the cow to exit and rejoin the herd (Peña-Lévano et al., 2025).

The Large-Scale Survey in Both States

In early 2024, we conducted a comprehensive survey in California and Wisconsin, targeting 2,000 dairy farmers

Figure 1. AMS Milking Process

from both states. The survey covered labor availability, technology adoption (AMS and other automation), perceptions and utilization of dairy support programs, and sustainable practices. Sections of the questionnaire used in this study—which focuses on farmer and farms' characteristics, labor, and automation—are described in Table 1.

The Survey Research Center (SRC) at the University of Wisconsin–River Falls implemented the survey on our behalf, which included survey distribution, data collection, cleaning, and compilation. The SRC utilized the Dillman (1978) Total Design Method to ensure systematic and robust data collection. The approach included sending a postcard reminder to nonrespondents 3 weeks after the initial mailing, followed by a second survey to nonrespondents 3 weeks after the reminder postcard. Based on survey research literature (Hoddinott and Bass, 1986) and prior experience of the SRC, this method is documented to boost the survey response rates in a cost-effective manner. Data collection was conducted over an 8-week period and concluded in April 2024.

To construct statistical estimates with a 5% margin of error and within a 95% confidence interval, a minimum sample size of 363 responses was needed. Stratified sampling was utilized to ensure that the overall sample is balanced relative to the population of dairy farmers in each state. The contact information of the 2,000 survey recipients of both states was obtained from multiple sources. For California, the SRC used the US Farm Service Agency (FSA) mailing list of all payment recipients from the Dairy Margin Coverage program—a low-cost insurance program in which most dairy farmers participate. For Wisconsin, the SRC utilized the list of licensed milk producers obtained from the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP).

The survey yielded 556 complete responses—100 from California and 456 from Wisconsin—resulting in a 28% response rate and exceeding the minimum sample size needed for statistical validity, which provides robustness to our analysis. The following sections discuss the major findings related to key challenges in labor retention and supervision, barriers and motivators for AMS adoption, and adoption of additional automated technologies in dairy operations.

Dairy Farming in California and Wisconsin

Despite comparable contributions to the US milk supply, dairies in California and Wisconsin operate under distinct economic and operational structures. As the nation's largest milk producer, California benefits from a topography and climate that is favorable for cattle and milk production, supporting a flourished dairy industry (Sumner, 2020). In 2021, California dairies produced 41.9 billion pounds of milk—about 19% of the US milk supply—generating $57.7 billion in economic activity (California Dairy Press, 2022).

The most common nonrobotic milking facility reported by our California survey respondents was the herringbone pit parlor—where cows stand on an elevated platform at a 45-degree angle to the operator pit, allowing easy access to the cows' udders. Most of the dairy farms (87%) were nonorganic (conventional), with an average of 918 acres and 2,143 dairy cows in their operations,

Table 1. Survey Questionnaire on Labor and Automation
Farmer's characteristics
Role: Owner, manager, employee Age group: 18–24, 25–34, 35–44, 45–55, 56–65, 65+ Annual household income in 2023 Off-farm employment (farmer and spouse): Yes, full-time; Yes, part-time; No
Farm and herd
Primary milking facility: Stanchion barn, tie stall, free-flow, guided flow, others Organic operation: Yes, No Number of acres Number of Holstein and Jersey cows Average age (in years) of milking cows Frequency of milking (per day) Average culling rate, mortality rate and replacement rate
Farmers' perception of labor and industry situation
Mental health and stress, outlook of the farm and dairy industry Increased difficulty (in the last 12 months) in finding quality workers, training, supervising and retaining farmworkers Percentage of farmworkers that have worked on the farm for more than 1 year Number of family, nonfamily and foreign-born employees in the farm Average hourly wage paid to workers
Automated milking systems (AMS)
Current AMS adoption: AMS adopter, potential adopter, prefer manual milking Factors preventing AMS adoption: Expensive to purchase and install, too costly to maintain, too difficult to manage, access to plenty of manual labor, herd size is too small, current good enough milking system, etc. Factors leading AMS adoption: Expand herd size, reduce reliability on employees, farm labor is too expensive, potential higher milk yield, reduce time spent managing the herd, current milking system worn out, modernize the farm for succession, etc. Type of robot: Lely, DeLaval, Boumatic, Galaxy, GEA Year of the first robot installed

largely comprised of Holstein cows (displayed in Table 2). This aligns with Sumner (2020), who states that approximately 70% of the dairy sector in California consists of midsized and large operations (>500 cows). The potential for economies of scale and the need for skilled dairy managers are among the reasons motivating the consolidation of the California dairy industry. In 2007, there were about 2,000 dairy farms in the state; by 2017, only 1,279 remained in operation (Sumner, 2020).

Wisconsin—commonly known as America's Dairyland—has the largest number of dairy farms in the United States. However, this number has dropped dramatically, faster than in California, from 11,542 herds in March 2012 to only 5,321 license herds in March 2025 (USDA-NASS, 2025). This means that more than half (54%) of Wisconsin dairy farms closed operations in just 13 years. Despite this decline in the number of farms, overall milk production in Wisconsin has increased by about 18% during this period and the state of Wisconsin currently accounts for 14% of the US milk output, making it the second largest milk producer (USDA-NASS, 2025; Peña-Lévano et al., 2025).

Unlike California, Wisconsin dairy operations tend to be much smaller, an average of 608 acres and 247 dairy cows, according to our survey responses. Parabone pit parlors—which arrange cows at a 70-degree angle to the operator pit—were reported to be the most common facility (Table 2), likely to allow more cows (in a smaller space) relative to herringbone pit parlors.

In California, senior farmers (56+ age group) comprised more than half of the respondents (58%), with 70% of owners earning more than $75,000 annually. In contrast, most of Wisconsin farmers (59%) are in the middle-age group (35–55 years old), with only half (50%) of the dairies earning more than $75,000. These results can be attributed to the difference in the size of operations and ownership in both states.

Decomposing the labor force into full-time and part-time employees (as depicted in Figure 2), the survey shows that about 91% of California farms hire external labor, with immigrants accounting for 43% of the total workforce—aligning with the findings of Charlton and Kostandini (2021). Family members support the dairy operation on a part-time basis, constituting almost half of the part-time employees. The sum of both payrolls constitutes about 12% of the cost of the California milk production (Sumner, 2020).

In Wisconsin, most of the dairies (about 95%) are family-owned (Peña-Lévano, Burney, and Beaudry, 2023), relying heavily on family members, which comprise

Table 2. Dairy Farms in California (CA) and Wisconsin (WI)

	CA	WI	Distributional Test Results
Nonrobotic milking facilities[a]			
Flat parlor	19%	9%	***
Herringbone pit parlor	56%	40%	***
Parabone pit parlor	24%	51%	***
Age group			
18 to 34 years old	10%	4%	***
35 to 55 years old	32%	59%	***
56+ years old	58%	38%	***
Income group			
<$75,000	30%	50%	***
$75,000–$150,000	41%	30%	***
>$150,000	29%	20%	***
Certified organic			
Organic	13%	8%	
Traditional	87%	92%	
Average land and herd size			
Acres	918	608	***
All cows in the herd	2,143	247	***
Jersey cows (average)	503	7	***
Holstein cows (average)	1,863	242	***
Farmer off-farm labor			
Full-time employment	1%	4%	
Part-time work	9%	9%	
No outside activities	90%	87%	
Observations (*N*)	100	456	

Notes: We performed chi-squared tests for percentage distribution variables and the Mann–Whitney U test for land and herd size (MacFarland and Yates, 2016). Triple and doube asterisks (***, **) indicate significance at the 1% and 5% levels, respectively (99% and 95% confidence).
[a]Approximately 25% of farmers reported “other” milking parlor. These were not included in the table because most did not specify the type of parlor.

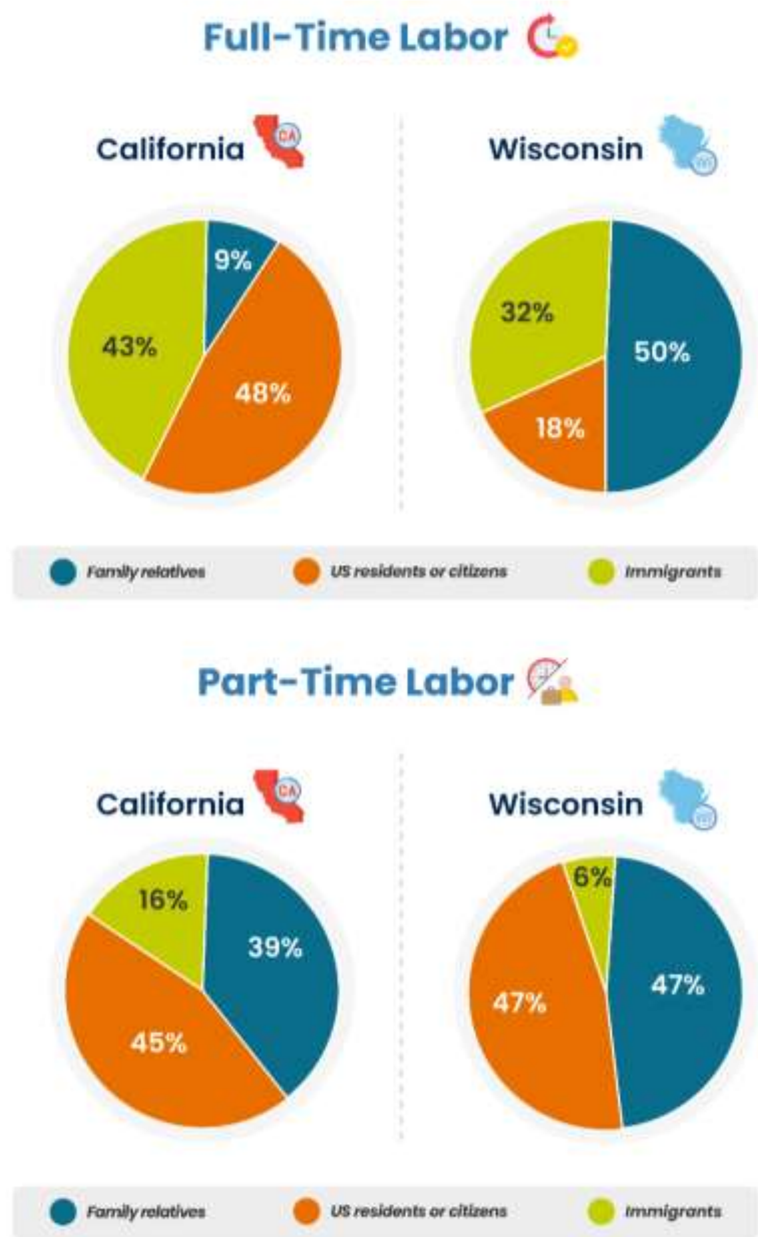
almost half of the full-time employees. Most part-time workers (84%) were reported to be either domestic labor or family relatives, making the labor sources (statistically) different from California.

Adoption of Milking Robots

The adoption of AMS in California and Wisconsin is still in its infancy. Only 4.7% of surveyed respondents (hereafter referred to as AMS farmers) reported that they have already adopted robotic milking. The majority of farmers (approximately 80.5% from both states) reported that they operate with manual (or conventional) milking systems and would not adopt AMS. This estimate is consistent with the 4% AMS adoption rate in Wisconsin unveiled in the 2024 DATCP survey (DATCP, 2024). Similarly, a recent exploratory survey conducted by Darby (2022) found that only 8.7% of respondent farmers utilize AMS in the US Northeast.

A third group—categorized as potential adopters (14.8% of all our respondents)—expressed that they currently do not have AMS but are considering making the investment. Figure 3 shows how sociodemographic characteristics differ across the three groups (AMS farmers, potential adopters, and manual systems).

Figure 2. Labor Demand in California and Wisconsin



Consistent with Peña-Lévano, Burney, and Beaudry (2023), experienced farmers—who usually own larger operations—are keener to adopt AMS due to their financial capacity and as a strategy to reduce their working hours and thus improve their quality of life.

Most farmers in all groups (30%–37%) fall into the middle-income category, earning between $75,000 and $150,000 per year. Almost a quarter of potential adopters and AMS farmers reported earnings over $150,000, compared to only 12% of farmers who prefer manual milking systems. This can be partially attributed to the size of their operations. While farmers with robotic milking or contemplating their adoption tend to farm the most land (AMS farmers: 965, potential adopters: 839 acres), manual farmers run smaller operations (average = 621 acres). Likewise, most AMS adopters (88%) reported a higher milking frequency (more than twice a day) compared to 79% of manual milkers who milk twice daily. This is likely due to the labor required for manual milking, which is challenging amid labor shortages, especially in Wisconsin, as noted anecdotally.

Why Are Farmers Choosing to Adopt or Not Adopt AMS?

The survey reveals similar reasons why AMS is adopted in California and Wisconsin. Among possible drivers, dairy farmers in both states indicated their primary motivation for automation is to reduce reliability on

Figure 3. Summary Statistics by Adoption Group

employees. This result was expected because labor shortages are of major concern for the dairy industry (Charlton and Kostandini, 2021). In California, the limited supply of domestic farmworkers cannot meet the need for full-time, year-round employees. In Wisconsin, where farms are largely family-run, the shortages come in the form of part-time workers that provide intermittent support in tasks such as milking, fetching cows, and managing herds. This situation is exacerbated by the incompatibility of the H-2A guest worker program, as the seasonal nature of H-2A employment does not align with the year-round demands of dairy farming (Escalante et al., 2019).

Farmers with aging milking systems (that will soon need to be replaced or will require a major repair) were motivated to automate their operations and thus remain competitive. Furthermore, the prospect of higher milk yield from cows voluntarily milking about three times daily incentivizes AMS adoption by offering potential revenue gains (Salfer et al, 2017). Wisconsin farmers also responded that their intentions of expanding herd sizes align with the automation of the milking process, consistent with the positive correlation between both practices (Martinsson et al., 2024).

The survey also shows that—independently from the state—the major barrier to modernize a parlor to a fully-robotic setting is the high upfront cost, estimated at approximately $250,000 per robot box. Considering each box milks between 60–70 cows daily, an average 250-cow Wisconsin farm would require an initial investment of about $1,000,000. In addition, the farm must incur expenses for either new infrastructure (free-flow or guided barn) or retrofitting an existing barn (Peña-Lévano et al., 2025). Maintenance expenses—ranging from $7,500 per year in the initial stages to as much as

$16,500 annually as the system ages—further discourage investment (Bentley, Schulte, and Tranel, 2018). These barriers may particularly constrain middle- and low-income farmers from installing AMS in their operations, as it can represent a large financial burden.

Dairy farmers that perceived their current system as still functioning efficiently and those that were unclear about the benefits of AMS also expressed no interest in purchasing robotic milking systems. This can be attributed to the fact that despite the vast literature studying AMS in Europe and New Zealand, there are limited studies addressing the feasibility of AMS in the United States. Likewise, previous research also provides conflicting findings. These are summarized in a review by Jacobs and Siegford (2012), which attributes AMS benefits to improvements in management practices and facility design when the technology is adopted. In the same line, Steeneveld et al. (2012) report negligible differences in labor costs, net output, or technical efficiency in their Dutch study. Thus, it is still not clear whether this technology's net benefits outweigh its costs (Peña-Lévano, Burney, and Beaudry, 2023). Last, Wisconsin dairy farms also report that without a clear successor to take over the operation, long-term capital investments such as AMS become less appealing to farmers.

How Are Labor Challenges Correlated with Automation?

In addition to labor shortages, the dairy sector also faces issues with labor retention, with a national turnover ratio averaging 38.8% in 2019 (Ribero, Adcock, and Anderson, 2020). Turnover imposes severe financial burden on dairy operations, estimated at 150% to 250% of a worker's annual wage due to recruitment, onboarding, and productivity losses (Billikopf and González, 2012). Our survey (Figure 4) underscores the severity of these challenges. One-third of dairy farmers reported substantial difficulty in securing skilled labor,

Figure 4. Perception on Labor Issues

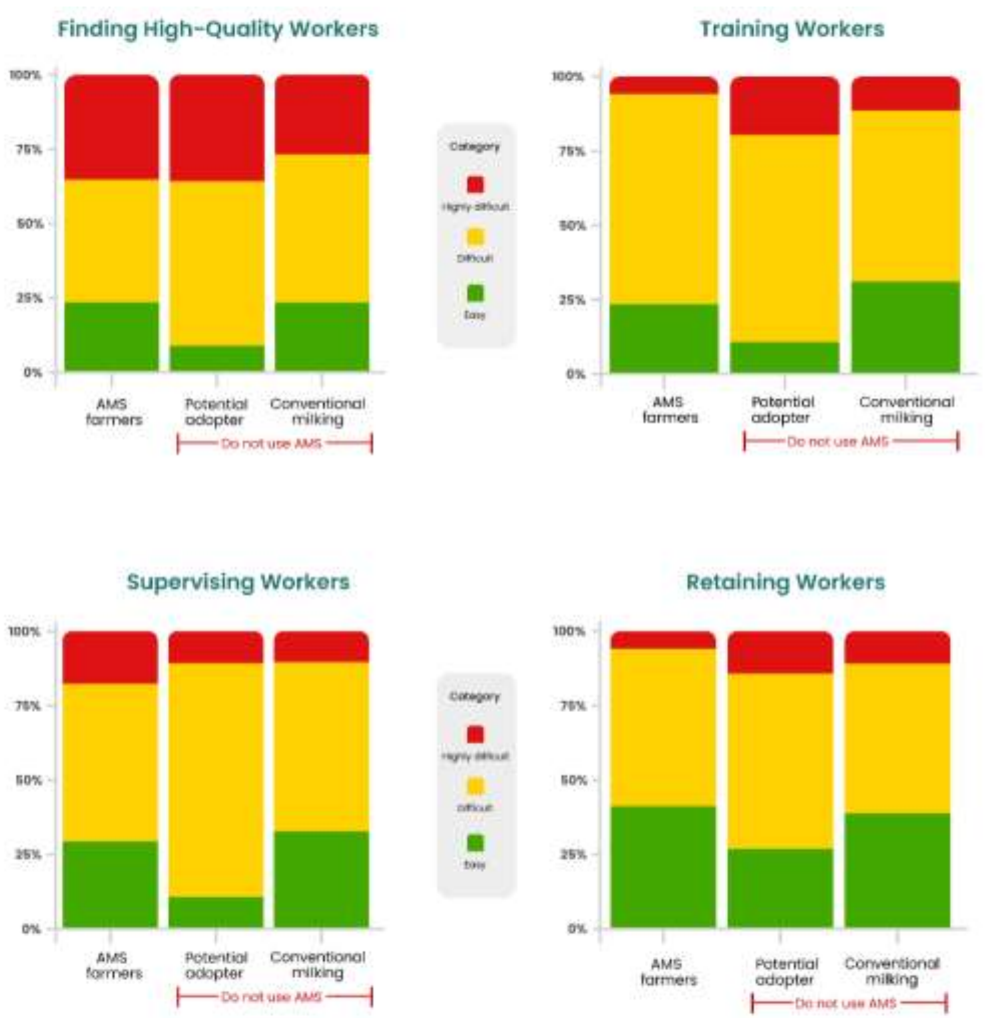
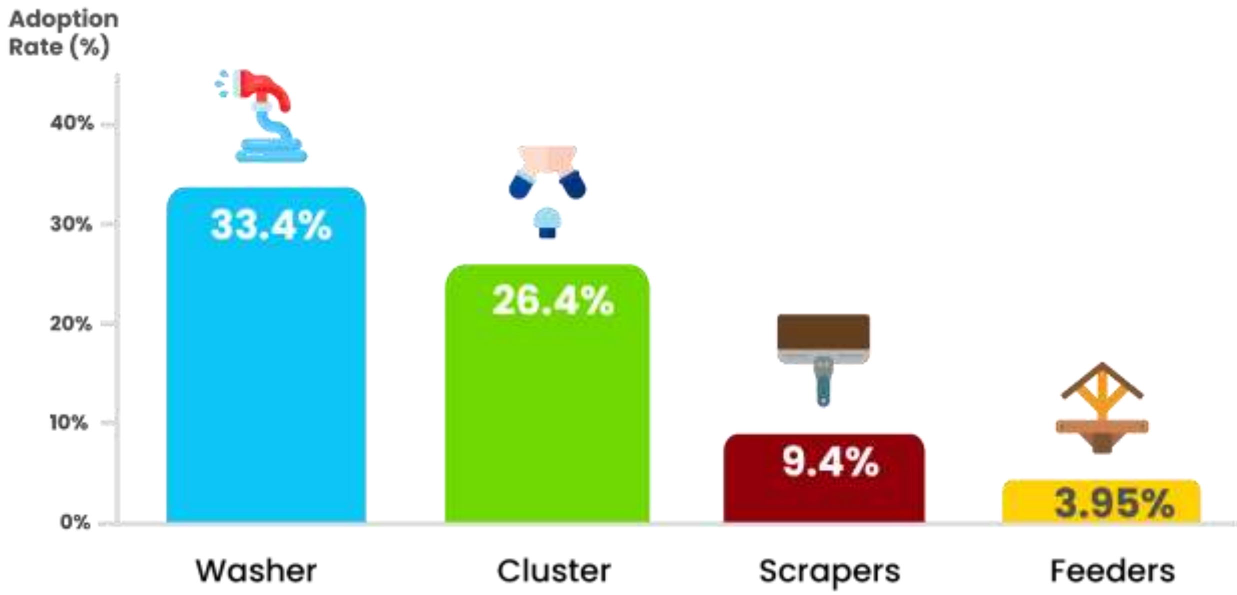


Figure 5. Ancillary Dairy Technologies



while more than half struggled with employee retention. Notably, farmers considering AMS adoption perceived greater challenges in hiring, supervising, training, and retaining workers than those who are largely uninterested in automation, suggesting that AMS serves as a strategic response to labor market constraints. However, farmers with a manual milking system had a similar satisfaction with and ease in finding, training, and retaining workers as AMS farmers, which explains why they chose not to adopt AMS.

Beyond economic implications, labor retention is also a social concern. Previous studies have emphasized the fact that wage increases alone do not fully resolve the issue. In a 2009 survey, Billikopf and González (2012) interviewed 209 dairy workers in selected California counties, finding that, in addition to compensation and benefits, workers also left their employer because of existing economic problems at the operation, working schedule, and family matters.

The Emerging Use of Other Automated Technologies

Beyond AMS, dairy farms are integrating a range of automated technologies to reduce labor reliance in specific tasks such as cleaning and feeding (Garcia-Covarrubias et al. 2023). Among the most common ancillary systems are automatic washers, cluster removers, scrapers, and feeders.

Automated washers play a critical role in maintaining hygiene by using high-pressure water and chemical detergents to sanitize milking equipment and parlors, reducing bacterial contamination and the risk of mastitis. Automatic cluster removers prevent overmilking by detaching milking clusters once milking is complete, thereby reducing teat stress and improving cow comfort. Automated scrapers help maintain barn cleanliness by systematically removing manure from alleys, while automated feeders deliver precise portions of feed tailored to each cow’s nutritional needs, optimizing herd management and efficiency (Palma-Molina et al., 2023)

Our survey results indicate that more than two-thirds of responding farmers (N = 403) have adopted some form of automation (illustrated in Figure 5), with automatic washers being the most prevalent (33.4%), followed by automated cluster removers (26.4%), automatic scrapers (9.4%), and automated feeders (4.0%). While automated washers are considered standard in modern dairy operations, responses suggest that some farmers may not perceive their systems as fully automated or only report recent investments in automation.

Concluding Remarks

Dairy farms in California and Wisconsin face persistent challenges in recruiting, supervising, training, and retaining skilled labor. These issues—particularly labor shortages and high turnover—are key factors motivating some producers to consider automating the milking process. Although AMS adoption remains limited, approximately 15% of surveyed producers identified themselves as potential adopters, reflecting the growing interest in automation as a tool to improve labor efficiency and reduce dependency on increasingly hard-to-find workers.

However, this interest is far from uniform across all dairy operations. Our results suggest a more nuanced picture: One group of manual milking farmers, often operating at a smaller scale with more stable and family-based labor, reports fewer challenges in worker management and show limited interest in transitioning to AMS. In contrast, traditional farmers managing larger herds and experiencing labor challenges such as difficulty with recruitment, supervision, and retention express greater openness to adopting AMS technologies. This distinction highlights that labor pressures might be concentrated in certain segments of the dairy sector.

Among AMS adopters, average profits appear higher than nonadopters; however, these differences may broadly reflect variations in farm size rather than the technology itself. Previous research remains inconclusive on whether AMS-driven milk yield and operational efficiency improvements sufficiently offset the substantial investment and maintenance costs. Given these uncertainties and financial constraints, many producers are turning to ancillary technologies—such as automatic washers, cluster removers, feeders, and manure scrapers—as partial solutions to automate specific labor-intensive tasks without the full commitment to robotic milking systems.

The findings from this study offer important insights for dairy producers, policymakers, and technology developers. Our results highlight the value of weighing AMS adoption against farm-specific factors such as labor reliability, operational scale, and capital availability for medium to large dairy operations. In regions where farms depend more heavily on hired labor, policymakers might explore targeted incentives as a strategy to encourage automation. Moreover, AMS manufacturers and service providers can use these findings to adapt their technologies to better fit the needs of different farm sizes and management styles.

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For More Information

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The Unexpected Battle Against Avian Flu in US Dairy

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Current Developments

What was initially brushed off as an anomaly soon became a concerning situation. At the beginning of Spring 2024, dairy farmers across several US states noticed an unusual decline in milk production without complete certainty as to the cause (Ly, 2024). A few weeks later, in April, the news broke: Multiple dairy herds in Texas, New Mexico, Idaho, Ohio, Kansas, Michigan, and North Carolina had been diagnosed with avian flu—a similar strain that wreaked havoc on bird populations worldwide in 2022 (Neumann and Kawaoka, 2024). The recent detection of avian influenza type A(H5N1) in dairy cattle marks a worrying development that warrants careful monitoring.

Traditionally, avian influenza (avian flu) has primarily affected birds, but recent strains have demonstrated the ability to infect cattle, raising concerns about the potential for a national and international widespread infection (Caserta et al., 2024). The outbreak has continued to spread to other states, recently reaching California, South Dakota, and Wyoming. This evolving situation necessitates heightened vigilance and robust biosecurity measures to manage and mitigate the virus' impact on the dairy industry and potential spread to humans (Silva del Rio et al., 2024). As of February 10, 2025, the US Department of Agriculture (USDA) has confirmed 968 herd outbreaks across 16 states (CDC, 2025).

Lessons from Past Avian Flu Outbreaks in US Poultry

Highly pathogenic avian flu strains like A(H5N1) and A(H5N2) have historically impacted birds, posing significant risks to animal and public health (Zamani, Bittmann, and Ortega, 2024). In the United States, the first outbreak occurred in 1983–1984, primarily affecting poultry, with no reported human infections (Lupiani and Reddi, 2009). The 2015 outbreak—driven by the A(H5N2) strain—led to the culling of over 50 million birds across 21 states (Zhao et al., 2019), costing US turkey producers about $225 million (Çakır, Boland, and Wang, 2018).

The recent 2022–2023 outbreak involved the A(H5N1) strain, resulting in 1,172 outbreaks across 48 states, affecting commercial poultry farms (46 million laying hens, 10 million turkeys, and 3 million broiler chickens) (USDA-APHIS, 2024a). The pattern of this outbreak aligns with known migratory bird routes and the density of poultry-farming operations, highlighting regional disparities, with Minnesota (172 outbreak sites) and South Dakota among the hardest-hit states (CDC, 2023). However, only one human case was reported, in Colorado, linked to occupational exposure during poultry-culling operations, with no sustained human-to-human transmission detected (WHO, 2024).

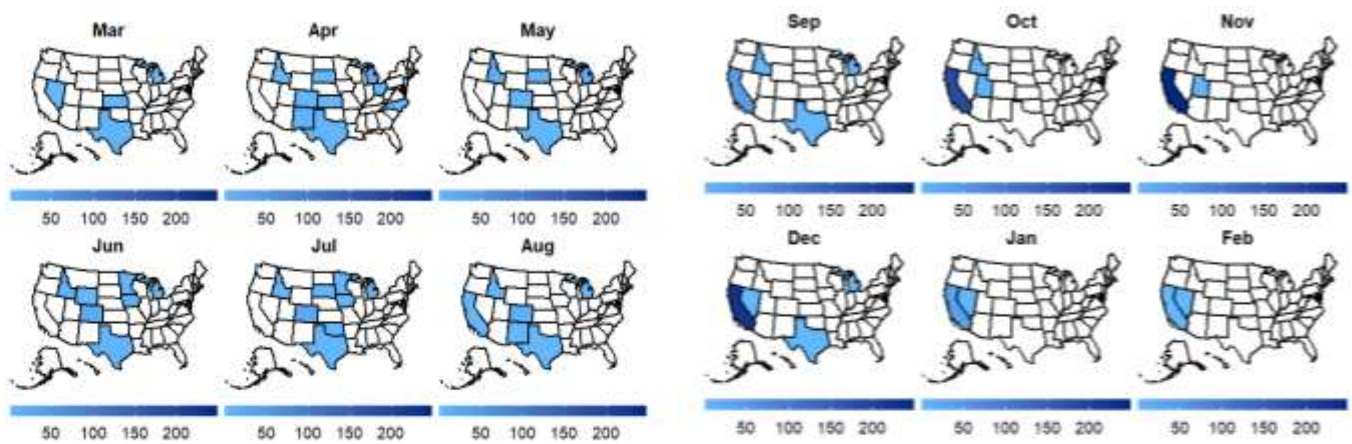
Hinsz (2023) highlights the common misconception that avian flu can be transmitted through properly handled and cooked poultry, which influenced consumer purchasing decisions. The economic impact of this belief extended beyond poultry, affecting price premiums for differentiated egg products like organic and vegetarian-fed eggs (Zamani, Bittmann, and Ortega, 2024). Further, similar misconceptions have affected the dairy industry in regard to safety of consuming pasteurized milk (FDA, 2024a) and meat products (USDA-APHIS, 2024c) that have undergone FDA and USDA inspection processes. Evidence-based data from both the FDA and USDA confirm that the processing standards effectively eliminate any risk of H5N1 transmission, ensuring the safety of both products for consumers (FDA, 2024a; USDA-APHIS, 2024c).

The 2024–2025 Avian Flu Outbreak in Cattle

In March 2024, avian flu A(H5N1) was detected in a Texas dairy herd, making it the first known transmission to cattle in the United States (Silva del Rio et al., 2024). Figure 1 displays the spread of avian flu in dairy cattle from March to February 2025, showing a total of 968 outbreaks. The most significant spread occurred in

Figure 1. Avian Flu Outbreak in Dairy Cattle

State	Cases
California	745
Colorado	64
Idaho	35
Michigan	30
Texas	27
Iowa	13
Utah	13
Minnesota	9
New Mexico	9
Nevada	7
South Dakota	7
Kansas	4
Oklahoma	2
North Carolina	1
Ohio	1
Wyoming	1



Source: The authors created the maps and table using data from CDC (2025), updated on 2/10/2025.

October–December, with California being the hardest-hit state.

While not fully understood, initial spillover of the virus to cattle may have occurred through the transmission of influenza A(H5N1) to cattle through indirect contact with contaminated environments, such as water sources or surfaces exposed to infected bird droppings (WHO, 2024). Wild migratory waterfowl—natural reservoirs of the virus—may also contribute to its spread (Caserta et al., 2024). Once infected, cattle can spread the flu through the air and possibly also through their milk (FDA, 2024b). However, cattle are less effective than birds at spreading the virus, indicating a less progressive dissemination of the virus through bovine-to-bovine transmission (Neumann and Kawaoka, 2024).

The United States responded swiftly to address this emerging virus outbreak, with the USDA mandating nationwide testing and reporting protocols for interstate movement of lactating dairy cattle, recommending the implementation of enhanced biosecurity measures, including specific mandates for quarantine and movement restrictions (USDA-APHIS, 2024c; FDA, 2024a). Affected farmers have received financial support to implement these protocols (USDA, 2024a). California is enforcing stricter controls on cattle imports to safeguard its dairy industry and provides additional biosecurity equipment to farmers (CDFA, 2024; Office of Governor Gavin Newson, 2024). Last, the USDA launched a national testing initiative before cattle interstate movement to identify outbreaks in its earliest stages and reassure consumers (McNeil, 2024).

International trade partners like Canada and Mexico introduced additional testing and quarantine requirements for US cattle imports to prevent the spread of A(H5N1) into their herds (AVMA, 2024; Garrison, 2024; Global Ag Media, 2024). The US dairy industry, which relies heavily on exports to maintain profitability, could face substantial economic losses if these restrictions persist or are expanded. Such trade restrictions (extended quarantine and testing requirements) could slow down the supply chain, increase export costs, and reduce competitiveness in the international market (Muhammad and Kilmer, 2008). Additionally, reduced demand from key trade partners due to biosecurity concerns could lead to a surplus in domestic markets, depressing prices and exacerbating challenges for US dairy farmers already dealing with tight margins and rising production costs (Peña-Lévano, Burney, and Beaudry, 2023; Wolf, 2024).

Clinical and Economic Impacts on Dairy Cattle

Clinical manifestations of avian flu in dairy cattle have varied across reported cases, including respiratory distress, fever, decreased feed intake, a marked reduction in milk production—of major concern for dairy farmers—and abnormal milk appearance, which may include a thick, yellowish milk (USDA-ARS, 2024; AVMA, 2024). Few cattle have shown severe symptoms, and most cattle are believed to remain asymptomatic (USDA, 2024b; WHO, 2024). The number of cows infected with A(H5N1) that die—known as mortality—has remained low, around 2%, much lower than has been observed in infected birds, where mortality is reported to be above 90% (ACVP, 2012). In contrast, most affected cattle with A(H5N1) recover with appropriate supportive care (WHO, 2024).

The presence of the virus in milk—even in the absence of symptoms—has raised significant food safety concerns. Initial findings suggested the possibility of viral transmission through milk to human populations through the food chain, leading to public alarm (Caserta et al., 2024; FDA, 2024b; NIH, 2024; Rust, 2024). However, subsequent studies confirmed that standard pasteurization effectively neutralizes the virus, ensuring that milk and dairy products are safe for consumption (US Department of Health and Human Services, 2024; Silva del Rio et al., 2024). According to the FDA (2024b), raw (unpasteurized) milk poses a risk for A(H5N1) infection and is a potential source for various other pathogens that could be transmitted through milk, leading the FDA to discourage the consumption of raw milk.

Although food products properly inspected by the FDA and USDA arriving at consumers' tables are safe from A(H5N1), the virus may have long-term implications for the dairy industry, including potentially reduced productivity in dairy cattle and impacts on animal health, for which more research is needed to better understand and evaluate potential impacts.

The FDA (2024a) has emphasized the importance of maintaining high safety standards, particularly in handling and processing milk from herds affected by the outbreak. As a precaution, milk from infected cattle is largely diverted from the commercial supply chain until thoroughly treated and tested (WHO, 2024). This practice ensures consumer safety and helps maintain public confidence in dairy products during outbreaks.

Concerns about the safety of meat products from affected cattle have been addressed through extensive testing on ground beef samples by the USDA's Food Safety and Inspection Service (FDA, 2024b). Using advanced polymerase chain reaction techniques, the US Food Safety and Inspection Office (FSIS) has consistently found no evidence of the virus in these samples (AVMA, 2024). This means that despite viral particles presence in infected cattle, these fragments do not necessarily represent a viable threat to human health (WHO, 2024).

There are two potential economic implications to the outbreak: negative perception of dairy products, which can be reflected in prices, and production costs due to sick animals and loss of productivity.

Concerning consumer perception, Figure 2 shows the average retail price for whole and 2% reduced-fat conventional and organic milk. Despite the first confirmed A(H5N1) cases in early spring, there is no noticeable decrease in the retail prices of these four milk products. This shows a different market dynamic in milk prices compared to previous avian flu outbreaks in poultry prices (Çakır, Boland, and Wang, 2018). This may suggest effective response to consumer concerns regarding the safety of dairy products by industry, academia, and extension.

The second concern is on supply disruptions, which include the cost of caring for sick animals, reduced milk production, stringent biosecurity measures, and the potential culling of infected cattle (Moya et al., 2020; FDA, 2024a). Resulting financial strains may lead to fluctuations in the dairy supply, market prices, and availability of products for consumers. To ameliorate these possible effects, the USDA has introduced financial aids for producers affected by A(H5N1) to enhance on-site biosecurity and compensate for lost milk production (Abbot, 2024; USDA, 2024b). Further, additional funding is available to facilitate biosecurity measures and viral testing for producers whose herds have not tested positive for A(H5N1) (USDA, 2024b).

As mentioned, broader implications extend to potential disruptions in the international trade of dairy products. For instance, countries importing milk and cheese from the United States (Canada and Mexico) may impose additional restrictions, further threatening the financial stability of US dairy farmers (Nganje, Steinbach, and Yildirim, 2024; CDC, 2024a).

Figure 2. Average Retail Prices for Conventional and Organic Milk, by Months of 2024

Notes: The price represents the most common brand in nonreturnable containers.

As highlighted above, avian flu may pose an economic burden for dairy farmers. Due to its sudden emergence, no prior research offers guidance for milk producers on the cost that this outbreak may represent for the dairy operation. This section presents an exploratory analysis focused on production loss (in $) due to the required quarantine period. Table 1 outlines the key assumptions and variables in our analysis.

Our analysis assumes that a cow produces an average of 70 lb of milk daily (Johnston and DeVries, 2018). According to biosecurity protocols, a cow infected with avian influenza must be quarantined for 30 days. After the initial 30-day quarantine, the milk is retested. If the result is negative, the cow is reinserted into the herd, but if it is positive, the quarantine is extended for another 30 days (Greene, 2023). Recent research suggests that milk disposal is only needed if a cow develops mastitis symptoms within the first 10 days of quarantine, with most infected cows recovering afterward (Petersen, 2024;Diaz, 2024). We assume that all standard production and animal husbandry practices continue during this period, as farmers must keep feeding and milking infected cows to prevent other health issues such as mastitis (CDFA, 2024). Since there has been no significant drop in dairy milk prices following the first human case of avian flu (April 1, 2024), we assume that prices remain stable (as shown in Figure 2) and thus focus our analysis on supply-side losses.

We assume that avian flu affects all dairy cattle breeds similarly, although individual variations in symptom response may occur (AVMA, 2024). For this cost analysis, we assume, based on WHO (2024), that an ill dairy cow will recover with proper supportive care, including medication and antibiotics that based on practical evidence range between $6 and $70 per cow. For this analysis we assume a treatment cost of $30 per cow. Additionally, we have assumed a labor time reallocation of approximately 30 minutes per cow for attending to and medicating the infected animals considering a $15 hourly wage (USDA-ERS, 2025).

Table 1. Key Assumptions Exploratory Analysis

Variables	Assumptions
Daily average milk production per cow	70 lb
Average milk price	$23/cwt (100 lb) for liquid milk
Quarantine time	30 days (up to 60 days). 10 days for cow recovery. Retail prices and consumption are constant
Farmers perception	Farmers apply treatment and care for cows. About 30 minutes per day (15 $ wage per hour). Production and feeding activities remain constant. No mastitis The cost for milk disposal is 0

Source: The authors created the table using data from the Milk Producer Council September 2024 Weekly Report.

Table 2. Exploratory Analysis Results

1 Number of Cows	2 Milk per Day (lb)	3 Daily Cost ($/cwt × lb/100)	4 Treatment cost	5 Value (Daily Cost × 30 days)
1	70	16.1	30	198.5
2	140	32.2	60	397
5	350	80.5	150	992.5
10	700	161	300	1,985
25	1,750	402.5	750	4,962.5

Notes: Column 3 shows the equivalent daily price of $23 per 100 lb per number of pounds produced shown in Column 2.

Source: The authors created the table using data from Class I Milk Price reported by the MPC Weekly Friday Report of September, 2024.

Based on these assumptions, Table 2 presents avian flu's estimated economic impact on an average dairy farm. If a single cow tests positive for avian flu and is removed from the herd for 30 days, production is disposed for 10 days, production losses could reach approximately $198.5 (column 5). If this virus spreads, for example, 5, 10, or 25 cows test positive, total losses would amount to $992.5, $1,985, and $4,962.5, respectively (column 5). These estimates align with the $100–$200 range calculated by the American Association of Bovine Practitioners (Hossain et al., 2024).

On average, dairy farms generate a profit ranging from $985 to a loss of −$1,303 per cow (Penn State Extension, 2022). Therefore, potential avian flu-related losses could significantly reduce profits by $198.5 per cow and even exacerbate existing losses, provoking financial stress among dairy operations.

Safety Measures That Help Prevent and Respond to Avian Flu Outbreak on Farms

The 2024–2025 outbreak underscores the importance of early detection and rapid response to limit the virus's spread, especially in dairy producing states. Comprehensive and practical enhanced safety measures (biosecurity measures) are essential, including regular monitoring and testing of cows showing symptoms, quarantine, sanitation, and controlled access (Wagoner, 2024). Figure 3 outlines biosecurity measures designed to assist dairy farmers in preventing and responding to an avian flu outbreak. The prevention path is depicted as a sequence of proactive measures to minimize the risk of avian flu introduction into a dairy operation. Regular testing emphasizes frequent monitoring and testing of cattle, particularly new arrivals, to detect any early signs of infection. Quarantining new arrivals ensures that any cattle introduced to the herd are temporarily isolated to prevent potential spread. Sanitation and disinfection highlight the critical role of rigorous cleaning practices in eliminating the virus from equipment, vehicles, and facilities, thus reducing the likelihood of surface-based transmission. Controlling access and movement stresses limiting farm access and monitoring personnel movement to prevent the introduction of the virus from external sources.

Vaccines are considered an important measure to help with prevention of infections in a herd. A(H5N1) vaccines have not yet been used in dairy and beef cattle in the United States, but influenza vaccines have proved effective in commercial pigs and poultry, and research efforts evaluating vaccines for A(H5N1) strain for cattle are currently ongoing (Reardon, 2024; USDA-APHIS, 2024b).

The response path involves key actions once an infection is suspected or confirmed. Symptom detection emphasizes promptly identifying signs of avian flu in cattle, such as respiratory issues or reduced milk production. If symptoms or positive test results are found, the infected cattle will be isolated for 30 days to prevent the virus from spreading. Reporting to authorities is crucial for tracking the outbreak and receiving support. Activated enhanced biosecurity, including stricter sanitation and movement restrictions, should be implemented.

Handling infected milk remains essential to managing the avian flu outbreak in dairy farms. Crossley et al. (2024) recently provided experimental evidence supporting milk acidification as a biosecurity intervention, demonstrating that citric acid treatment can successfully inactivate H5N1 in contaminated milk. This intervention could complement existing biosecurity protocols, particularly for farms that do not have immediate access to pasteurization facilities.

Farm Workers in Dairies

The ongoing outbreak has underscored the significant risks faced by farm workers. The first reported human case occurred in Texas on April 1, 2024, involving a dairy farm worker who contracted A(H5N1) after direct contact with infected cattle. The worker exhibited mild symptoms, primarily conjunctivitis, and recovered without complications (CDC, 2024a). In May 2024, two additional cases were reported in Michigan involving farm workers at separate dairy farms (MDHH, 2024a; MDHH, 2024b). Notably, one of these cases initially

Figure 3. Biosecurity Measures for Dairy Farmers Against Avian Flu Outbreak

Source: Authors. Based on the information from the CDC (2025) and the WHO (2024), updated on 1/10/2025.

tested negative on a nasal swab, but an eye swab sent to the CDC later confirmed the presence of A(H5N1) (CDC, 2024b). This case may highlight the risks associated with indirect exposure, as the worker is suspected of becoming ill through contact with contaminated surfaces (CDC, 2024b). The fourth case emerged in Colorado in July 2024, where a farm worker experienced mild symptoms, including fatigue and conjunctivitis, after working with infected cattle (FPC, 2024; CDC, 2024b). As of February 2025, the total number of human cases linked to exposure in commercial cattle operations has risen to 41. The majority of affected individuals experienced mild symptoms that resolved without requiring hospitalization (CDC, 2025).

Farm workers play a critical role in biosecurity, serving as the first line of defense against outbreaks. Training programs must emphasize early detection, properly handling contaminated materials such as nonsalable milk, and use of personal protective equipment (PPE) (Neumann and Kawaoka, 2024). Continuous education ensures that workers remain updated on the latest biosecurity practices and prepared to respond effectively to potential outbreaks. For instance, in states like Texas, Michigan, and Colorado, adherence to PPE and safety protocols has been vital in preventing the spread of A(H5N1) among workers (USDA-APHIS, 2024c).

In addition to these measures, it is also recommended that farm workers regularly exposed to (potentially) infected birds and cattle receive the seasonal flu vaccine (CDC, 2024a). Although the vaccine does not protect against the A(H5N1) virus, vaccinating at least 2 weeks before exposure can reduce the incidence and severity of the seasonal flu and lower the risk of a coinfection with the avian virus (Caserta et al., 2024).

Ensuring Public Confidence and Government Support

The success of managing the avian flu outbreak in the US dairy industry hinges on maintaining public confidence in dairy product safety and ensuring robust government support (Neumann and Kawaoka, 2024). Transparent communication and effective government policies are critical, and this could explain the stability of milk prices shown in a previous section. Publicizing rigorous safety standards, such as the diversion of milk from infected cattle and stringent testing protocols, helps maintain consumer confidence (FDA, 2024a).

Government support is vital, with the USDA providing financial aid to farmers (USDA, 2024b; USDA-APHIS, 2024c) and policy initiatives to enhance biosecurity technologies and establish emergency funds or insurance schemes for zoonotic diseases. Ongoing research and development efforts are necessary to improve the detection, management, and prevention of avian flu in dairy cattle. (Neumann and Kawaoka, 2024).

Conclusion

The 2024–2025 avian flu A(H5N1) outbreak in the US dairy industry represents a critical juncture for the agricultural sector and public health. This outbreak has demonstrated the significant risks that zoonotic diseases pose to livestock, the economy, and the food supply chain. As the outbreak evolves, the lessons learned and measures implemented must be used to outline blueprint for continuing efforts to increase the safety and security of food chains against potential future infectious disease outbreaks.

For those dairies whose herds exhibit symptoms, on average, about 10%–20% of each affected herd appears to be impacted, with little to no associated mortality reported (USDA-APHIS, 2024c). Thus, farmers play a crucial role in this, as they can detect and remove infected cows early by monitoring for signs of infection. Likewise, the findings of this study on the economic impact of avian flu on an average dairy farm highlight the urgent need for proactive management strategies to prevent or mitigate infestation risks.

A key takeaway from this situation is the critical importance of rigorous biosecurity measures. Acting quickly and following safety measures helped stop the virus from spreading. Government support, in the form of financial aid and policy initiatives, has also played a vital role in mitigating the immediate economic impact and potentially aid in building long-term resilience within the industry (Ly, 2024). Maintaining public confidence through transparent communication and stringent food safety standards has been equally essential in ensuring consumer trust in dairy products during this challenging time.

However, the fight against avian flu does not end with these immediate responses. Continuous research is paramount to advancing our understanding of the virus's transmission patterns, updating treatment protocols, and improving biosecurity technologies. The economic impact of the outbreak, particularly on dairy farms and related industries, warrants further investigation. A detailed economic analysis, similar to those conducted after previous poultry outbreaks (Moya et al., 2020; Hinsz, 2023), can provide valuable insights into market dynamics, consumer behavior, and the long-term financial stability of the dairy sector.

In summary, while the 2024–2025 avian flu outbreak has tested the resilience of the US dairy industry, it has also underscored the importance of preparedness, innovation, and collaboration among government, research, and industry. The ongoing efforts to combat this virus will not only safeguard the current agricultural landscape but also lay the foundation for a more robust and resilient food system in the future.

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What Do Dairy Farmers Think of Sustainability? Economic, Demographic, and Sociological Antecedents of Sustainable Practices

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In recent years, climate change mitigation has focused on reducing greenhouse gas (GHG) emissions from agricultural practices (Liang et al., 2017). In the United States, the agriculture sector emits about 11.2% of GHG emissions (US EPA, 2020), but the agriculture, food, and related industries add only 5.6% to the US GDP (USDA-ERS, 2023). This mismatch between the size of emissions and economic benefit has in part made it vital for farmers to incorporate sustainable farming to reduce their environmental footprint. Within the livestock sector, ruminants—beef and dairy cattle—are responsible for most of the non–carbon dioxide (CO2) emissions (Rotz, 2018). Enteric fermentation from dairy cows is the largest source of emissions, contributing about 35%–45% of total GHGs on well-managed confined farms (Rotz and Thoma, 2017; Innovation Center for U.S. Dairy, 2023). Moreover, the environmental impact of dairy farms has worsened over time. Capper, Cady, and Bauman (2009) estimated that the average dairy farm in 1944 had less than one-half of the carbon footprint per cow relative to modern high-producing farms.

Sustainable agricultural practices aim to preserve natural resources, ecosystems, and biodiversity on farms (Piñeiro et al., 2020). However, such investments can often be costly and impose a disproportionate burden on small-scale farmers. As a result, while practices such as crop rotation/diversification, no-till, efficient water use, and nutrient management can offset some of the adverse environmental impacts, their utilization is not yet widespread (Martin et al., 2017). This can be partly explained by farm-level economic pressures resulting from years of low commodity prices, natural disasters, the COVID-19 pandemic, and recent increases in feed, freight, fertilizer, and fuel costs (Newton, 2021; Liebrand 2022). For dairy farmers, rising input costs have reduced profit margins in recent years from $11.92/ cwt in June 2022 to only $3.65/cwt in June 2023 (USDA-FSA, 2024). This issue is even more salient in Wisconsin, America's dairyland, which has the largest number of dairy farms in the country, a large majority of which are small-scale. In 2022, among the roughly 6,000 dairy farms in Wisconsin, the average herd size was 203.4 cows (Hadachek and Deller, 2024). Thus, while farmers may perceive sustainability and environmental stewardship to be valuable endeavors, they may not have the capacity or resources to pursue them. The purpose of our study was to identify the factors that shape farmers' perception of sustainability and the decision to utilize sustainable practices, and to evaluate if favorable perceptions lead to greater utilization of these practices. Using an exploratory survey of Wisconsin dairy farmers, we analyzed the associations between economic, demographic, and sociological/personal factors and perceptions and utilization of sustainable practices.

Methodology and Data

In early 2024, we conducted a large-scale survey of Wisconsin farmers on sustainability-related topics. The survey was commissioned and funded by the Soil Health and Agroecological Living Lab (SHALL) at the University of Wisconsin–Madison. The Survey Research Center (SRC) at the University of Wisconsin–River Falls managed the data collection on our behalf. The SRC distributed 3,200 surveys and received 943 responses (29% response rate), 307 of which were from dairy farmers. Given the total population of 5,617 milking herds in Wisconsin by February 2024 (USDA-NASS, 2024), the sample of 307 allows for the development of estimates within a margin of error of 5.4%, somewhat higher than the statistical standard of 5%. Nonetheless, the sample size matches or exceeds the sample size used in similar exploratory studies of dairy farmers in Wisconsin. The survey included a gamut of questions that elicited perceptions of sustainability and the utilization of sustainable practices. Perceptions were measured using climate change beliefs and opinions on environmental stewardship and were quantified using a 5-point Likert-scale ranging from "strongly agree" to "strongly disagree." Questions on utilization asked about current use of sustainable practices. We also included a battery of farm- and farmer-related questions. Table 1 shows the distribution of the sample across these attributes. In terms of farm attributes, almost all farmers in the sample were owners and well over two-thirds had 20 or more years of farming experience. Farm size was measured in number of milking cows and acreage. Based on number of cows, about 61% of farms can be considered small (1–199 cows), 27% can be considered

Table 1. Descriptive Statistics & Baseline Survey Results

Role on the farm	Owner	Hired manager	Tenant		
	96%	2%	2%		
Years of experience	10 or less	11–15	16–20	21+	
	9%	6%	8%	77%	
Total number of milking cows	1–99	100–199	200–499	500+	
	61%	15%	12%	12%	
Total number of acres	1–199	20–499	50–999	1,000+	
	31%	31%	18%	20%	
Farm profitability	Very or moderately unprofitable	Breaking even	Moderately or very profitable		
	9%	22%	69%		
Gender	Male	Female			
	87%	13%			
Age	18–34	35–49	50–64	65+	
	12%	29%	39%	21%	
Education	High school or less	Some college/2-year degree	Bachelor's degree	Graduate degree	
	52%	31%	15%	3%	
Household income	< $50k	$50k–$75k	$75k–$100k	$100k–$150k	$150k+
	29%	17%	16%	15%	22%
Political affiliation	Democrat	Democrat-leaning independent	Independent	Republican-leaning independent	Republican
	9%	7%	17%	23%	44%
Belief that climate change is happening	Yes	No	I don't know		
	44%	32%	24%		
	Currently Use				
Manure application and crediting	82%				
Conservation tillage	46%				
No-till	43%				
Cover cropping	54%				
Diverse crop rotation	44%				
Nutrient management	53%				
Grazing	85%				
Organic (certified)	28%				

Notes: The percentages presented in Table 1 are based on a sample of 307 dairy farmers that responded to our survey. The survey was distributed to 3,200 Wisconsin farmers in January 2024. A total of 943 valid responses were received, for a response rate of 29%. Among the 943 farmers who responded, 307 reported having a dairy enterprise.

Source: Authors' calculations.

medium-sized (100–499 cows), and 12% large (500 or more cows). In terms of acreage, almost one-third (31%) of farmers reported having fewer than 200 acres, 49% between 200–999 acres, and 20% reported having more than 1,000 acres. Over two-thirds (69%) stated that their farm is moderately or very profitable, 22% reported breaking even, and 9% stated that their farm is moderately or very unprofitable. Regarding farmer attributes, a large majority (87%) identified as male and the remaining 13% identified as female. Only 12% of farmers indicated that they are in the 18–34 age range; over two-thirds (68%) of the farmers are in the 35–64 age range and about 21% are seniors (age 65 or older). About half of the farmers reported having no post-secondary education and only 18% have at least a college degree. About 54% of farmers in the sample reported a household income of over $75,000 per year. For reference, the median income of Wisconsin households is $74,631 (US Census Bureau, 2024). In terms of political affiliation, two-thirds (67%) of the farmers identified as Republican or as Republican-leaning independent. Regarding perceptions of sustainability, about 44% of the farmers stated that they believe climate change is happening. For this study, we considered only those sustainable practices that are either used by a large proportion of dairy farmers (e.g., manure application, no-till, cover cropping) or are considered impactful for sustainable production (e.g. grazing and organic). About 85% of the farmers use at least some grazing and 28% have certified organic operations.

Results

In this section, we present the association of economic, demographic, and sociological/personal factors with the perceptions of sustainability and sustainability-related issues and the likelihood of utilizing sustainable practices. Results are shown in Tables 2-4.

Economic Factors

The economic factors we considered for this study were farm profitability and household income. The question on farm profitability asked farmers to indicate how profitable their farm is on a scale ranging from “very unprofitable” to “very profitable.” For household income, we used the US Census income categories with truncation at $200k. For profitability, we compared farmers who are “very” or “moderately” profitable to farmers who are breaking even or “very” or “moderately” unprofitable. The threshold for household income was $75,000 per year. Table 2 shows the results.

Table 2. Perceptions and Utilization of Sustainable Practices by Economic Factors

	Profitability			Household Income		
	Very or Moderately Profitable	Breaking Even or Unprofitable	Diff. (percentage point)	> $75k	$75k or Less	Diff. (percentage point)
Utilize sustainable practice						
Manure application and crediting	83%	81%	3	85%	84%	0
Conservation tillage	48%	42%	6	51%	44%	7
No-till	48%	35%	12**	53%	40%	13***
Cover cropping	60%	44%	16***	58%	56%	2
Diverse crop rotation	49%	35%	13**	44%	48%	-4
Nutrient management	58%	47%	11*	61%	52%	9
Grazing	83%	88%	-5	82%	87%	-5
Organic (certified)	28%	26%	2	27%	28%	-1
Crop rotation						
Corn on soybeans	57%	44%	13*	58%	49%	9
Corn on corn	63%	66%	3	65%	61%	4
Corn on alfalfa	87%	86%	0.8	86%	88%	-2
Believe in climate change	47%	40%	7	46%	45%	1
Opinions on land stewardship						
Value minimizing soil disturbance	66%	63%	3	70%	63%	7
Value maximizing living cover	67%	60%	7	65%	65%	0
Feel personally connected to land	76%	74%	2	73%	79%	-6
Believe farmers are stewards of land	93%	91%	2	94%	91%	3

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. The generally accepted standard for statistical significance is $p \leq 0.05$.

Source: Authors’ calculations.

Farm profitability seems to be an important determinant of both perceptions of sustainability and utilization of sustainable practices. With one exception (grazing), farmers who consider their farm to be profitable were more likely to utilize all sustainable practices included in this study. The difference between profitable farms and their counterparts in the proportion of farmers who utilize no-till, cover cropping, and diverse crop rotation is large and statistically significant. Profitable farmers are also 11% more likely to utilize written nutrient management plans, although the difference is only weakly statistically significant. Similarly, profitable farms are 9% more likely to utilize a corn-on-soybean rotation. The benefits of corn-on-soybean rotation include added soil nutrients, increased yields, and reduced pests and disease (Sexton, 2019). Part of this result can be explained by the economic cost involved in implementing sustainable practices which may, at least temporarily, outweigh the benefits. For many sustainable practices, including no-till, the benefits are contingent on continuous use and are generally realized over a long period of time (Robertson et al., 2008; Cusser et al., 2020, Che et al., 2023). Profitable farms may be in a better position to absorb the initial economic loss than farms that are only breaking even or are unprofitable. Our results show that profitable farmers also have more favorable views on sustainability. While not statistically significantly, profitable farmers are 7% more likely to believe in climate change and value practices that minimize soil disturbance and maximize living cover.

Interestingly, household income does not have a sizable association with perceptions of sustainability or utilization of sustainable practices. The only statistically significant difference by income is that higher-income farmers are more likely to use no-till. There also does not seem to be a major difference by income in the proportion of farmers who believe in climate change, and while higher income farmers are 7% more likely to value practices that minimize soil disturbance, there is virtually no difference in the proportion who value practices that maximize living cover.

Demographic Factors

Demographic factors considered in our analysis include farm size (in number of milking cows), farmer age, years of experience, and level of educational attainment. Table 3 shows the perceptions of sustainability and utilization of sustainable practices by each demographic attribute.

Farm size is linked with several outcomes. As shown in Table 3, there is sizable variation by farm size across almost all sustainability practices. Relative to larger farms, farms with fewer than 200 milking cows are less likely to utilize all major sustainable practices except grazing and certified organic production. They are statistically significantly less likely to use conservation tillage or no-till, cover cropping, nutrient management, and corn-on-soybean and corn-on-alfalfa crop rotations. Conversely, smaller dairies are less likely to utilize corn-on-corn rotations, a crop management technique that usually leads to lower yields, especially in years of climatic stresses, relative to a diverse crop rotation such as corn-on-soybeans (Al-Kaisi et al., 2024). Farm size is also linked to perceptions of sustainability. Small-scale farmers were less likely to agree that climate change is happening or that they value farming practices that minimize soil disturbance.

These results imply that in the decision to utilize grazing and organic production, sustainability may not be a major factor for small-scale farmers. Even though they are less likely to utilize other sustainable practices, about 92% of small dairies indicated that at least some of their acres are dedicated to grazing, compared to only 55% of larger dairies, a statistically significant 37-percentage-point difference. This may be because the labor and management costs of moving cows between fields are typically greater for larger herds, due to the economies of scale of growing feed (Felix et al., 2023), and that smaller pastures are often a better fit for rotational grazing (Bates, 2022). Similar factors may explain why smaller farms are more likely to be certified organic. McBride and Green (2009) used survey data to show that the need for acquiring organic inputs in large volumes can lead to constraints on scaling an organic dairy operation. In addition, it is often difficult for a farm that relies heavily on feed to accept the tradeoff of lower yields for organic crops (Panday et al., 2024).

To evaluate the influence of farmer age, we compared farmers who are 65 or older with younger farmers. The only statistically significant difference between the two age groups was that older farmers were more likely to use a nutrient management plan. However, farmers who are 65 or older seem to have a more favorable view of sustainability relative to younger farmers. Farmers who are 65 or older are more likely to believe that climate change is happening, value farming practices that minimize soil disturbance, and feel personally connected to their land. There does not seem to be a consistent story in how the number of years of farming experience is associated with perceptions of sustainability and utilization of sustainable practices. Farmers with 20 or more years of experience are more likely to use conservation tillage and nutrient management plans but less likely to use cover cropping, grazing, and certified organic production relative to farmers with less experience. In addition, a smaller proportion of these farmers report using diverse crop rotations, but a larger proportion indicated that they use a corn-on-soybeans production model. Perceptions of sustainability do not vary statistically significantly by years of experience, except that farmers with 20 or more years of experience were more likely to agree that they feel personally connected to their land. The level of education of the farmer is significantly correlated with the utilization of several sustainable practices. Farmers with more education than a high school degree are more likely to utilize no-till and nutrient management plans and be

Table 3. Perceptions and Utilization of Sustainable Practices by Demographic Factors

	Farm Size			Farmer Age			Years of Experience			Level of Education		
	< 200 Cows	200+ Cows	Diff. (percent . point)	Senior (65+)	< 65	Diff. (percent . point)	20+ Years	< 20 Years	Diff. (Percent. Point)	Some Colleges	High School or Less	Diff. (percent . point)
Utilize sustainable practice												
Manure application and crediting	81%	90%	-9	81%	84%	-4	82%	84%	-2	87%	81%	6
Conservation tillage	41%	64%	-23***	51%	43%	8	48%	35%	13**	49%	44%	6
No-till	35%	69%	-34***	46%	43%	3	44%	41%	3	56%	33%	23***
Cover cropping	50%	70%	-20***	49%	56%	-7	53%	61%	-8	55%	56%	-1
Diverse crop rotation	45%	46%	-1	37%	46%	-9	41%	57%	-16**	39%	50%	-11**
Nutrient management	41%	96%	-55***	67%	51%	16**	57%	41%	16**	67%	44%	23***
Grazing	92%	55%	37***	75%	86%	-11*	83%	90%	-7	76%	92%	-16***
Organic (certified)	33%	7%	25***	25%	27%	-2	23%	44%	-21***	33%	20%	13**
Crop rotation												
Corn on soybeans	50%	67%	-17**	51%	54%	-3	58%	39%	19**	53%	55%	-2
Corn on corn	58%	83%	-25***	65%	63%	2	66%	55%	11	64%	62%	2
Corn on alfalfa	85%	93%	-8*	94%	85%	9*	88%	84%	4	82%	92%	-10**
Believe in climate change	54%	40%	-14***	64%	41%	23***	44%	42%	2	59%	31%	28***
Opinions on land stewardship												
Value minimizing soil disturbance	61%	75%	-14**	78%	62%	16**	66%	61%	5	72%	59%	13**
Value maximizing living cover	65%	65%	0	65%	65%	1	63%	73%	-10	65%	65%	0
Feel personally connected to land	76%	74%	2	86%	73%	13**	80%	65%	15**	82%	71%	11**
Believe farmers are stewards of land	93%	91%	2	91%	93%	-2	92%	97%	-5	92%	94%	-2

Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. The generally accepted standard for statistical significance is $p \leq 0.05$.
Source: Authors' calculations.

certified organic producers. However, they are less likely to use diverse crop rotations, a corn-on-alfalfa model, and grazing. Note that, except for organic production, the utilization of sustainable practices by education aligns (inversely) with farm size. This is because farmers in our sample with more education than a high school degree are disproportionately more likely to own/operate larger farms.

Sociological and Personal Factors

The goal of this section of the survey was to determine whether sociological components and personal beliefs influence perceptions of sustainability and the decision to utilize sustainable practices. We evaluated three major variables: political affiliation, trust in scientists, and trust in the government. The latter two variables were measured using the farmer's level of agreement to the statements "I trust scientists" and "I trust the government," respectively. Table 4 shows the differences in responses the three variables. For political affiliation, we compared farmers who are Republican or Republican-leaning independent relative to farmers who are independent, Democrat-leaning independent, or Democrat. Evidence from literature suggests that political affiliation does shape farmers' views on climate change. For example, a survey of Nevada farmers found that Republican and conservative respondents view climate change as a low national priority and less harmful to themselves and their communities (Liu et al., 2014). Our results show that while political affiliation is associated with the belief that climate change is happening, the link with utilization of sustainable practices is not clear. Republican farmers are more likely to utilize no-till and nutrient management plans but less likely to use grazing and certified organic production. As with farm size, perceptions and practice of sustainability seem to diverge across political affiliation. In particular, the decision to use grazing and organic production does not align with the decision to implement other sustainable practices. Trust in scientists seems to be a major factor in farmers' belief that climate change is happening, in line with much research that the science of climate change is highly politicized among largely conservative populations (Liu et al., 2014; Chatrchyan et al., 2017). Farmers who distrust scientists are much less likely to believe in climate change, and there is a 25-

Table 4. Perceptions and Utilization of Sustainable Practices by Sociological/Personal Factors

	Political Affiliation			Trust in Scientists			Trust in Government		
	Republican	Independent /Democrat	Diff. (percent. point)	Distrust	Trust/ Neutral	Diff. (percent . point)	Distrust Govt.	Trust/ Neutral	Diff. (percent. point)
Utilize sustainable practice									
Manure application and crediting	87%	84%	3%	82%	86%	-4	87%	83%	4
Conservation tillage	49%	51%	-2	42%	51%	-9	47%	48%	0
No-till	54%	36%	19***	33%	53%	-20***	45%	45%	0
Cover cropping	58%	49%	8	57%	55%	2	55%	57%	-2
Diverse crop rotation	41%	41%	0	50%	41%	9	44%	46%	-3
Nutrient management	65%	48%	17**	43%	64%	-21***	53%	59%	-6
Grazing	75%	91%	-16***	88%	82%	7	83%	86%	-3
Organic (certified)	15%	41%	-25***	30%	24%	6	23%	30%	-7
Crop rotation									
Corn on soybeans	59%	42%	16*	48%	57%	-9	53%	54%	-1
Corn on corn	64%	59%	5	63%	64%	-2	66%	61%	5
Corn on alfalfa	85%	81%	4	87%	86%	1	84%	89%	-5
Believe in climate change	41%	68%	-17***	29%	54%	-25***	43%	48%	-5
Opinions on land stewardship									
Value minimizing soil disturbance	68%	65%	3	53%	72%	-19	64%	65%	-1
Value maximizing living cover	62%	63%	-1	63%	67%	-4	63%	69%	-6
Feel personally connected to land	81%	72%	8	75%	78%	-2	81%	72%	9*
Believe farmers are stewards of land	93%	89%	4	94%	92%	-2	95%	91%	4

Notes: *** p < 0.01, ** p < 0.05, * p < 0.10. The generally accepted standard for statistical significance is p ≤ 0.05.
Source: Authors' calculations.

percentage-point difference in that likelihood between farmers who distrust scientists and their counterparts. Whether a farmer trusts scientists also has some influence on the utilization of sustainable practices. Farmers who distrust scientists are less likely to utilize no-till and nutrient management plans. However, whether a farmer trusts the government does not have a tangible association with perceptions of sustainability or utilization of sustainable practices, suggesting that farmers distinguish between governmental and scientific sources of information. While some differences between sustainable practices are nontrivial (e.g. nutrient management and organic), they are not statistically significant. Similarly, while farmers who distrust government are 9% more likely to feel personally connected to their land, the difference is only weakly statistically significant.

Conclusion

We found several robust associations between economic, demographic, and sociological/personal factors and sustainability. Farm profitability and size seem to be the strongest determinants of sustainable practices. With few exceptions, farmers that consider their operation to be profitable are consistently more likely to utilize sustainable practices. Similarly, small-scale farmers are more likely to utilize only those sustainable practices that are a better fit for smaller scale enterprises: grazing and organic production. These differences are also significantly related to level of education, an important attribute that shapes both the utilization of sustainable practices and perceptions of sustainability. Farmers with higher education are more likely to believe that climate change is happening, value practices that minimize soil disturbance, feel personally connected to their land, and have organic operations relative to their counterparts.

A somewhat surprising result is that the association of political affiliation with sustainability is not consistent across the measures analyzed in this study. For example, in what may be considered contrary to popular belief, Republicans are more likely to utilize no-till production and nutrient management plans relative to farmers who have opposing political viewpoints. Yet farmers who are Republican are significantly less likely to believe that climate change is happening. Thus, there is an obvious dissonance between perceptions of sustainability and how sustainable practices are utilized, likely due to the politicization of climate change belief but not sustainable practices, which are seen as enhancing soil and water protection. This discrepancy can also be seen when comparing farmers across age. Farmers aged 65 or older are more likely to believe that climate change is happening, value minimizing soil disturbance, and feel personally connected to the land. However, this favorable perception of sustainability does not translate to action because, with one exception: Seniors (age 65 or older) are not statistically significantly more likely to utilize any sustainable practice relative to younger farmers.

Our study shows that not only is there substantial diversity in the economic, demographic, and sociological/personal factors that categorize dairy farmers, no one factor can fully explain how perceptions of sustainability are shaped and how they are manifested in farming practices. For example, even though there is an economic cost involved in transitioning to some sustainable practices, lower-income farmers are not much less likely to utilize sustainable practices across the board. Similarly, the primary determinant of grazing seems to be farm size, which outweighs the effect of other factors such as educational attainment. These results have important implications for the design of programs meant to mitigate GHG emissions from dairy farming. They suggest that policy interventions must be based on a multifaceted approach that incorporates farmers' economic, demographic, and sociological motivations for utilizing sustainable practices rather than simply alleviating the cost of such practices.

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After a Decade of Genomic Testing, Are Milk Yields Being Impacted?

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Over the past 40 years, milk yield per cow has tripled in the United States. According to animal scientists at the Council of Dairy Cattle Breeding, at least half of this increase can be attributed to improvements in dairy cow genetics by selective breeding, with the other half explained by management and environmental factors. These breeding efforts in the United States impact dairy farmers in the United States and worldwide. In 2022, the United States exported 47% of the total value of global bull semen exports, making it the world's number one exporter of bull semen.

The market for cattle genetics has undergone significant changes. Around 2010, the first "genomically tested" bulls entered the dairy bull genetics market. Genomic testing is a tool for selective breeding that allows dairy breeders to estimate an animal's potential traits nearly at birth through a DNA sample. Before genomic testing, dairy bull breeders could only understand a bull's traits by waiting until it had offspring with data on milk yield and health outcomes. Cattle breeders can now speed up this process by estimating a bull's ability with a DNA test, allowing them to select bulls to sell more precisely and market them much more quickly.

Data on dairy bulls sold in the United States from 2000 to 2020 show several significant structural changes in the dairy genetics industry. Since genomic-proven bulls hit the market in 2010, dairy farmers have three times more bulls to choose from, and a bull's semen is now sold a little before they are 2 years old instead of at 5 years old. Genomic testing also coincides with a substantial increase in bull productive ability: Since 2010, the rate of growth in the predicted milk yield ability of dairy bulls has doubled. The percent of bulls on the market that are genomically tested has also risen to over 90%. Yet a puzzle remains: While genetic improvement has taken off, the rate of increase in the national average milk yield has scarcely changed since 2010 and has even decreased in recent years (USDA-NASS, 2024). Only states with smaller dairy herds (an average herd size of fewer than 500 cows) have seen marginal increases in the rate of milk yield improvement, opening up the possibility that the new revolution in genetic improvement is not increasing on-farm milk yields across the board.

The Supply of Dairy Bull Genetics

US dairy farmers predominantly use artificial insemination to breed their cows and raise future replacement cows. Instead of using a live bull, a farmer will buy semen from a bull sold by a genetics company or breeding cooperative. Farmers decide which bulls to breed with their cows by examining each bull's predicted genetic contribution to production and health outcomes and the physical characteristics of their offspring. These genetic traits include milk yield, pregnancy rate, milk cleanliness, and other health and production metrics. Three times a year, the organization Council on Dairy Cattle Breeding (CDCB) produces estimates of the contribution of each bull to its offspring's performance using data from dairy farms collected by Dairy Herd Improvement Associations (DHIAs) (Hutchins and Hueth, 2023). The CDCB publishes these estimates to help farmers understand how much, on average, the use of each bull will influence the characteristics of their future replacement.

Dairy breeders respond to farmers' demand for genetics by crossing female and male cows to produce bulls with desirable traits for the market. Once a bull is born, it takes at least 4 years to understand its traits with "daughter-proving," meaning estimating a bull's traits using data on its daughters (see Box 1). A dairy bull becomes sexually mature at around 1 year of age. Once used on a dairy farm, its offspring will take at least 3 years to be born and reach producing age (10 months of gestation and 2 years from birth until a cow produces milk). Due to the time required to collect data, a bull is usually around 5 years old before it is advertised for sale. The age difference between a bull and its parents

Box 1: How Is Genetic Potential Milk Yield Calculated for Dairy Bulls?

When choosing which bull to breed with, dairy farmers need to understand how each bull might impact the herd's milk production. They might also want to know how the bull's offspring will fare in terms of health and fertility. Using cow-level data from dairy herd improvement associations, the Council on Dairy Cattle Breeding produces bull genetic evaluations for traits like milk yield, which the industry can use freely. Each bull's genetic trait is calculated using a mixed linear model called the "animal model," which estimates the contribution of a dairy bull's genetics to its daughter's performance on multiple outcomes. For example, the milk yield genetic trait is calculated by measuring cow milk yield and determining how much variation in their milk yield can be explained by their father's identity. If all the daughters of one bull have high milk yields, even independent of other confounding factors, that bull will have a high "predicted transmitting ability" (PTA) for milk yield on the market. Each trait the CDCB calculates is a measure of a specific characteristic of the animal, such as productivity (e.g., milk, fat, protein yield), health (e.g., fertility, calving ability, predisposition to sickness), and physical characteristics (e.g., size of udders, foot health, body size).

is called the "generation interval" and directly influences how quickly dairy breeders can improve traits. The longer it takes to prove a genetic trait, the longer it will take for breeders to select and improve on that trait in the next generation.

In contrast to the daughter-proving method, genomic testing identifies genetic markers in each animal's DNA that correlate to desirable traits. Breeders can now take DNA samples from new animals and look for markers correlated with desirable traits. Using known correlations between genetic markers and production and health outcomes, a genomic test can estimate a dairy bull's genetic traits before it reaches sexual maturity.

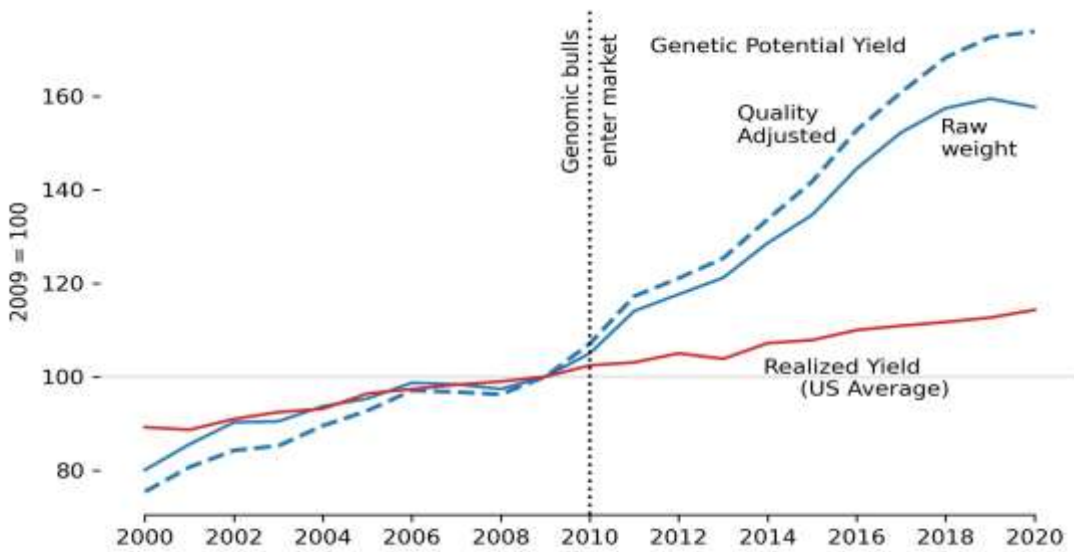
Genomic testing drastically reduces the generation interval because bulls can be used to breed the next generation of cattle from an even earlier age. The accuracy of a genetic trait prediction is referred to as the "reliability" and is reported as a percentage, where 100% indicates certainty that the trait will be transmitted to its offspring. Before genomic testing, a bull with no offspring would have an average reliability rating of 28%–38% using only information on its parents. In contrast, a bull with a genomic test has an average reliability rating of 65%–75%, even with no information on its offspring. With the inclusion of data on the production of its offspring, reliability usually gets closer to 90%–95%. The accuracy of the genomic test for a bull without offspring is expected to continue to increase as more animals are genotyped and more genetic markers are found (Wiggans et al., 2011).

Genomic testing has had at least three significant impacts on the structure of the dairy bull genetics market. First, the age at which a bull is first marketed has dropped considerably, according to the National Association of Animal Breeders (NAAB), a trade organization that publishes a list of bulls available for purchase in North America three times a year. Before genomically tested bulls arrived, the average age was over 5 years. After the introduction of genomic testing, the average age has dropped to less than 2 years, a little after a bull reaches sexual maturity. An accurate estimate of their traits without collecting data from offspring has allowed dairy breeders to market bulls nearly as soon as they can be marketed.

Second, according to the NAAB lists, the number of bulls available on the market has more than tripled. Starting in 2010, the number steadily increased from a little less than 500 before 2009 to more than 1,500 in 2020. This growth is entirely explained by genomic-proven bulls, who now account for the vast majority (over 90%) of the bulls on the market. Today, practically all bulls are genomically tested when they are born.

Third, the rate of change in genetic potential milk production, that is, how much more dairy bulls are predicted to increase milk yield, drastically increased after the introduction of genomic testing. This milk yield measure differs from the milk yield that dairy farmers see on their farms, as it is the milk yield change that the CDCB scientists predict will occur on average if a farm used that bull. For dairy bulls, the milk yield trait reported represents the genetic potential milk yield independent of other factors which can be more or less than the "realized" milk yield we would see on the farm or in aggregate data. In Figure 1, we can see the average genetic potential milk yield of dairy bulls for sale each year according to the NAAB, which measures the expected increase in pounds of milk yield from using each bull relative to bulls in the year 2000. The genetic potential yield for both raw weight and milk adjusted for the amount of protein and fat (standardized to 3.5% butterfat and 3.2% protein) increased over this period. Understanding raw weight and milk adjusted for components is especially important since most dairy farmers are paid based on components (butterfat, protein, and other milk solids) instead of raw weight. While the milk production ability of dairy bulls between 2000 and 2009 grew about 20%, it grew close to 60% from 2010 to 2020. Genetic potential for butterfat and protein also increased on the bull side. Genetic potential milk yield adjusted to have a uniform amount of fat and protein grew even more, almost 70% relative to 2009.

Figure 1. US Average Milk Yield versus Genetic Milk Yield



Genomic testing plays at least two significant roles in increasing genetic potential milk yield. The pace of change due to genetics is affected by both how selective breeders are about which bulls to use, referred to as "selection intensity," and the time it takes to produce offspring from a match, which is the generation interval. Genomic testing allows dairy breeders to identify undesirable genetic lines earlier and remove them from the genetic pool without having to wait and measure the production of a bull's offspring. The ability to be more selective at this stage amounts to an increase in selection intensity, which will cause the average genetic potential milk yield to increase more in each generation than before.

The average increase in genetic milk yield year-to-year also depends on the age of the bull when it produces offspring. The earlier a bull can be identified as productive, the younger it can be used to breed offspring. Thus, genomic testing decreases the generation interval, which causes genetic milk yield to increase more rapidly year after year. Combined, these two factors can help explain why the introduction of genomic testing caused an increase in the rate of change in traits dairy breeders find important.

While the adoption of genomically tested bulls at the farm level is not known, the percentage of genomically tested bulls on the market can be calculated from the NAAB bull lists. From these lists, we see that genomically-tested bulls quickly became the majority on the market. In 2010, the first year in which genomically tested bulls appear in the NAAB dairy bull lists, about 60% of the listed bulls were genomically tested. By 2015, 80% of the bulls on the list were genomically tested; by 2020, less than 5% of bulls were tested only using the daughter-proving method.

Genetic Potential Milk Yield and Realized Milk Yield

The rate of change in milk yield predicted by genetics has more than doubled, but how did this impact the realized milk yields reflected in aggregate data? While dairy breeders focus on understanding the impact of genetics, milk yields are also impacted by management factors such as feeding practices and new technology and environmental factors such as changes in temperature and humidity. The CDCB estimates that about 50% of the growth in milk yields can be attributed just to genetics. Part of the remaining 50% is environmental factors such as high temperature and humidity, which can depress milk yields. On the management side, improvements in feed quality and milking technology are also important components of milk yield growth.

Figure 1 plots the average annual production of a dairy cow as measured by the milk production reports published by the USDA National Agricultural Statistics Service (NASS). In contrast to the CDCB's measurement of genetic potential yield, this is the realized milk yield trend in the United States that reflects all factors, whether genetic or not. On the same graph, we plot genetic potential milk yield on the bull side and index both trends to 2009, 1 year before genomic bulls entered the market. Since our data only show the bull side, the improvements on the male side should represent no more than 25%–50% of the trend (bulls represent only half of the genetic trend, while female cows determine the other side). As the rate of genetic potential gain in milk yield sharply increased after 2009, we would expect a similarly noticeable increase in the US average milk yield trend.

Table 1. Average Annual Percentage Growth

Data Source	2000–2020	2000–2009	2010–2020
NASS			
Milk yield	1.35	1.37	1.33
Fat yield	1.71	1.34	2.00
DHIA records			
Milk yield	0.71	0.48	0.89
Fat yield	1.06	0.42	1.59
Bull genetic estimates			
Milk yield	3.48	2.53	4.26
Fat yield	5.04	4.08	5.83

Instead, we see no noticeable change in the national average trend after 2009. From 2002 to 2009, the US milk yield growth rate closely followed the genetic milk yield growth rate. Both increased about 10% in those 7 years. After the introduction of genomic-proven bulls in 2010, genetic potential milk yield grew 60% in 10 years while the US milk yield trend grew at approximately the same rate. In the last 2 years, we even saw this rate slow: Milk annual production per cow increased only 0.1% between 2022 and 2023 (USDA, 2024).

Table 1 breaks down the average annual percentage growth in milk yield and butterfat yield across three data sources: NASS, DHIA, and bull genetic estimates. While no trend break is visible in the US average, bull genetic estimates are estimated using herds that are members of dairy herd improvement associations (DHIAs). If herds participating in DHIAs are more productive than the US average, bull genetic estimates may reflect genetic change on only DHIA farms and not farms on average.

Before 2010, the average US milk yield increased by an average 1.3% annually, while genetic milk yield increased on average 2.53% annually. After genomics, the average annual growth rate of US milk yield has scarcely changed at 1.3% per year, while genetic milk yield has increased to 4.26%. While genomic testing appears to have caused a structural shift in genetic milk yield, US milk yield shows no such structural break. As measured on DHIA farms, milk yield appears to have increased rapidly over time but at a much lower rate (less than 1% growth a year).

To understand whether the trends in milk yields are similar across production systems, we break down milk yields in the 15 states with the most dairy cows with state-level data from NASS. We divide these states into "small herd states," where the average herd size is less than 500, and "large herd states," where the average herd size is more than 500. Figure 2 shows the small and large states and their average herd size in 2020. We use the 500-cow cutoff to divide states since it conveniently groups states geographically and is a good proxy for the different production scales in these two regions. Large dairy states are primarily in the Western United States and had an average herd size of more than 1,000 cows in 2020 (with the exception of Washington). Small dairy states are in the Midwest and Northeast and have more small herds, making the average herd size usually fewer than 300 cows.

Figure 2. Large and Small Herd States

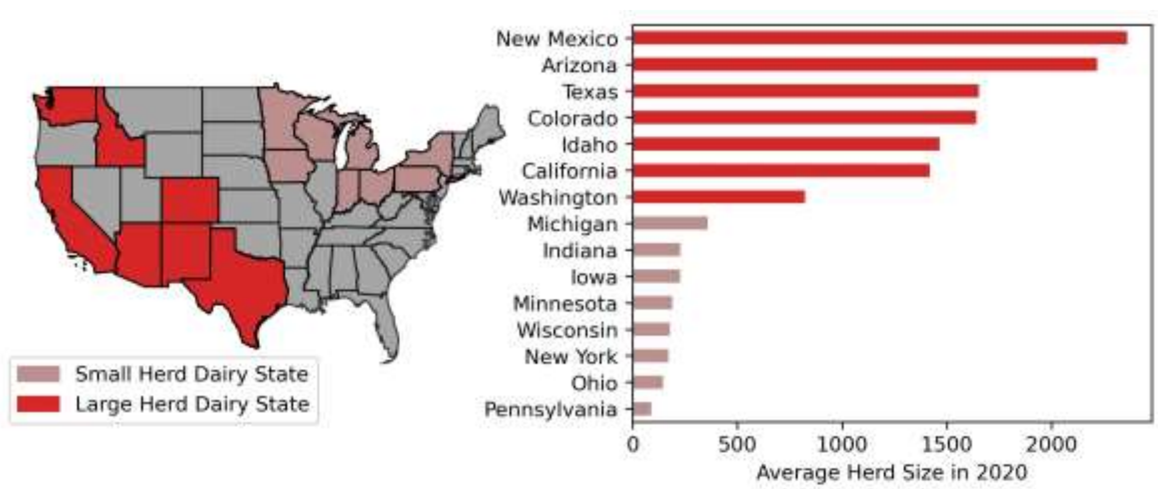
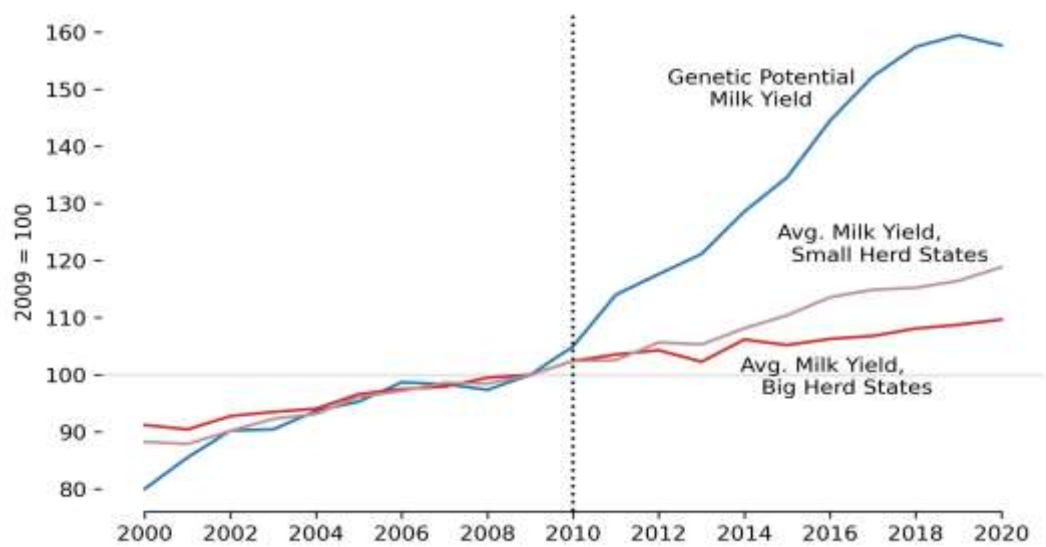


Figure 3. Genetic Milk Yield versus Milk Yield, Small and Large Dairy States



In Figure 3, we chart average milk yields in these two categories of states. As in the aggregate, milk yield trends in both states follow the genetic milk yield trend quite closely before 2009. However, starting in 2013, the rate of milk yield growth in small states began to outpace large dairy states. Since new genetic improvements will take at least 3 years to affect on-farm averages, this is consistent with dairy farms in small-herd states benefiting more from genetic improvements in the genomics era than those in large-herd dairy states.

Discussion

Why would the US milk yield average grow at the same rate while dairy bull genetics are predicted to deliver more milk yield than before? There are a number of possibilities. First, the adoption of higher-yielding genetics may not lead to higher milk yields on every farm. Some new bulls may produce more productive offspring in certain management environments or climates, a phenomenon quantitative geneticists refer to as “genotype-by-environment interactions.” These kinds of effects would lead to the efforts of breeders having different impacts in different circumstances, which may either enhance or depress the impact of genetic change on US milk yields. For example, farms that use sexed semen, which is almost guaranteed to produce female offspring, might choose dairy bulls that have higher productive ability since there is a higher chance what they chose will produce a replacement and not a male that will be sold for beef. One study on the adoption of dairy bulls in Wisconsin finds that a large portion of productivity can be explained by the type of herd in which the genetics are used (Hutchins et al., 2021). This might lead us to believe that smaller states have production systems where these genetics are the most productive, given differences in average farm size (Figure 3). Njuki (2022) also finds that medium-sized farms have productivity growth over the same period in USDA data that is consistent with the use of higher-yielding genetics.

Nevertheless, there is little reliable data on the cost of dairy bull genetics, and this data gap makes it difficult to assess whether the genomics bulls available on the market are worth the investment for many farms. However, we also know that above 90% of dairy bulls in the market currently are genomically tested from birth, making it relatively unlikely that dairy farmers are failing to adopt any of these high-yielding bulls. Understanding how farms see the costs and benefits of these new bulls requires more data on the cost of these bulls and a more precise understanding of which farms adopt them.

Another possibility is that genetic estimates derived from DHIA farm data do not reflect the US average. In Table 1, we see that milk and fat yield change their growth rates in DHIA data, which is the data from which genetic estimates are derived. However, the growth rate is so small that it raises questions of whether the changes in trends match the changes in the genetic trend. In 2022, about 44% of US dairy cows had records in the DHIA system. However, a previous study found that farms on DHIA tend to be more productive, which may mean they are more likely to have management styles that help dairy bulls have higher yield impacts (Khanal et al., 2010).

A third possibility is that another factor has depressed yields even despite higher rates of genetic change. While dairy cattle can be protected from heat more easily than crops, high humidity, and high temperature combinations can harm dairy cow milk yields (Key et al., 2014; Hutchins et al., 2025). However, for this to explain the lack of change in milk yield from genetics, it would need to be the case that heat stress conditions dramatically worsened in 2010 to coincide with genomic testing just enough to counterbalance the increase in genetic improvement. From what we know from studies of heat stress adaptation, dairy farms are becoming more resilient to heat stress, not less (Gisbert-Queral et al., 2021), making it unlikely that dairy farms became less resilient after 2010 to counter genetic change. Since average temperatures have risen gradually over time, we should have also seen the US average milk yield lag genetic change before 2010 instead of following it closely. While we do see the Midwestern states with lower summer temperatures have a higher rate of milk yield increase than the Western states, studies on heat stress losses on dairy farms find that the majority of losses are in Southern states (Key et al., 2014; Gisbert-Queral et al., 2021).

While we understand that genetic change has an essential role in productivity growth, some particulars remain hazy. Future research in economics may be able to explain these trends by exploring how farmers choose different bulls and what sorts of farmers are likely to choose high-yielding bulls (Hutchins et al., 2021). In particular, there is little research on how much these new bulls cost and whether the cost is low enough to justify adoption by farmers. More work is also needed to understand how the increased frequency of heat waves will impact the adoption of certain dairy bulls and which production systems will see the largest returns to adopting high-yield bulls in a changing climate. Understanding exactly how dairy breeders' efforts contribute to increased milk yield in these production systems is crucial for the future of the US dairy sector and an important topic for research and discussion.

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Beef-on-Dairy Crossbreeding Offers Additional Income for US Dairy Farms

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Why Are Dairy Farmers Looking for New Income Streams?

The dairy industry is a major source of income for the US economy. In 2024, its impact was estimated at $794 billion, accounting for 3.4% of its GDP and supporting 3.2 million jobs (IDFA, 2025). However, dairy farmers are currently grappling with high variability in net farm returns and farmgate milk prices, labor shortages and wage pressure (Son, Richard, and Lambert, 2022). More recently, a mutation of the avian flu capable of infecting dairy cattle has introduced further economic risks (Garcia-Covarrubias et al., 2025). As a result, many small- and mid-sized licensed herds, unable to cope with this turmoil, have opted to sell their assets and exit the industry (Peña-Lévano, Burney, and Beaudry, 2023).

Many of the remaining dairy farms—often referred as resilient farms—are actively exploring strategies to diversify their income streams. Notably, raising surplus crossbred bull calves in dairy operations has gained traction driven by their high sale price. This article discusses the economic implications of crossbreeding dairy cows with beef cattle for the dairy farms and cow-calf operations.

How Traditional Dairy Farms Work

US dairy farms predominantly raise Holstein and Jersey cows (Olthof, Domecq, and Bradford, 2023). To sustain milk production, heifers—young female cows that have not yet calved—are reared as replacements for aging cows. Heifers are typically raised for 22–24 months before their first calving, incurring feed, bedding, labor, and veterinary costs estimated at $1,129 per head (Heinrich, Tozer, and Gabler, 2022).

Traditional dairy farms are not equipped to raise bulls (male dairy calves). Newborn (0–14 days) purebred bulls are sold at auctions or through direct sales for veal or beef production (Berry, 2021). Some dairy farms use sexed semen in artificial insemination to increase the proportion of female calves, thereby reducing the number of male calves born and optimizing long-term herd profitability (Hutchison & Bickhart, 2016).

The US Steer Beef Production System

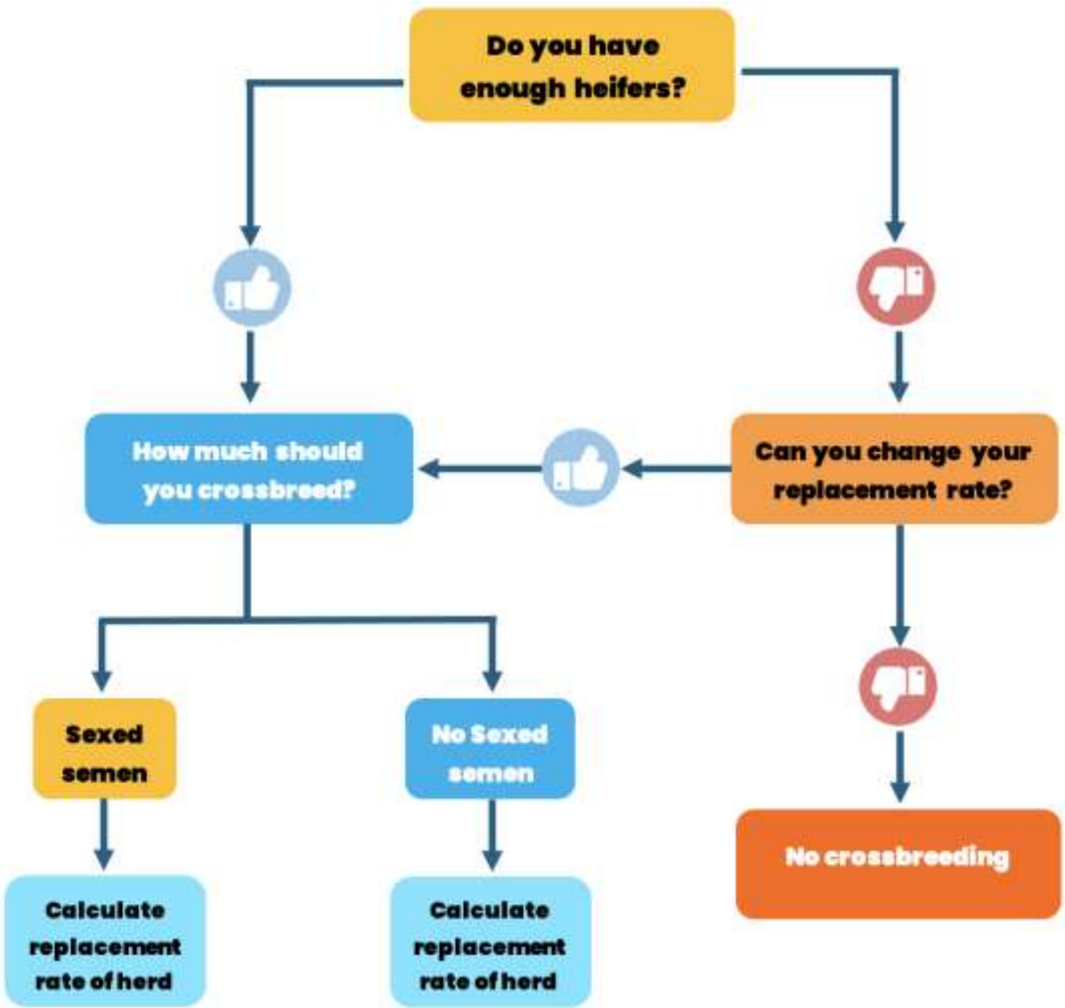
Pure US beef breeds are predominantly Angus, Charolais, Brahman, or Simmental (Drouillard, 2018). Typically, beef production comprises three stages:

1. Cow-calf operations, where calves are initially raised alongside beef cows for about half year. Beef cows and calves are primarily grazed on grass and pastures, promoting muscle growth in calves until they are separated from the cow (Knight, 2025).
2. Once the calf is weaned, he may either replace older bulls kept for mating or become a steer (after castration) to enter a stocker operation, where the animal grazes on extensive grassland until achieving a certain target weight (Drouillard, 2018).
3. After 3–6 months, the steer enters the final stage of production, where he transitions into feedlots where he receives a grain-based diet (corn, wheat, or sorghum) to enhance marbling and meat quality (Knight, 2025). In addition to grain, oilseed meals (soybean, cottonseed, sunflower, and canola) are fed as traditional protein sources, with byproducts of wheat and barley being used as energy sources in Washington and Idaho (Greenwood, 2021).

Crossbreeding in Dairy Farms

There is a growing use of beef sire semen in US dairy farms. In California alone, the largest US milk producing state, about 81% of dairy operations reported using beef semen in a 2020 survey (Latack and Carvalho, 2024). This shift is further reflected by a sharp rise in domestic beef semen sales, which surged from 2.7 million doses

Figure 1. Farmers' Decision Tree on Optimal Reproduction Strategies



in 2015 to 9.7 million doses in 2024. In the same period, there was a notable decline in purebred dairy sire semen, from 23.7 million doses in 2015 to 16.2 million doses in 2024 (NAAB, 2025).

Crossbreeding dairy cows with beef sires to produce beef-on-dairy offspring offers multiple benefits stemming from heterosis, defined as the superior performance of hybrid animals relative to the average performance of their purebred parents. Crossbreeding improves the reproductive performance and pregnancy rate of dairy cows (decreasing the need for heifer replacements) and yields better carcass weight and higher meat quality of dairy calves (Berry, 2021). As a result, crossbred calves are valued at a premium over purebred Holstein bull calves (Coleman et al., 2016). While purebred newborn bulls typically sell for around $50 per head, crossbred newborn calves are priced between $400–$600 per head (Torres, 2023). This significant price gap provides a clear incentive for dairy farmers to produce crossbred offsprings as a lucrative secondary income stream.

Economic Benefits of Crossbreeding for Dairy Farms

In this section, we present an economic framework that evaluates the potential profits from crossbreeding in a typical dairy operation. The model uses a decision tree framework (depicted in Figure 1) to simulate common reproductive management practices and assess their economic outcomes. It provides a structured approach for dairy farmers to make informed breeding decisions by balancing herd sustainability with potential revenue gains from crossbred calves.

Decision Tree on Reproduction Strategies

The simulation model begins by addressing a fundamental question: Does the dairy farm have enough heifers to replace older cows and maintain herd sustainability? If the answer is yes, then farmers can consider crossbreeding surplus dairy cows with beef sires to produce higher-value crossbred calves. The decision on how much of the herd to crossbreed depends on the farm replacement rate and the success of producing a female offspring.

If the answer is no, then farmers need to assess whether they can enhance cow health and longevity to reduce the need for replacement heifers. If this is feasible, then crossbreeding can still be pursued, especially when combined with sexed semen—which almost guarantees a female offspring but at a higher cost (Hutchison and Bickhart, 2016). Through genetic prioritization, high-performing cows can be bred with sexed dairy semen to secure purebred replacement heifers, while the remainder of cows are crossbred to produce higher-valued beef-dairy calves.

However, if the farm cannot reduce its replacement rate and lacks enough heifers, crossbreeding is not recommended, as it could compromise herd sustainability, essential for long-term farm stability.

Economic Scenarios and Assumptions

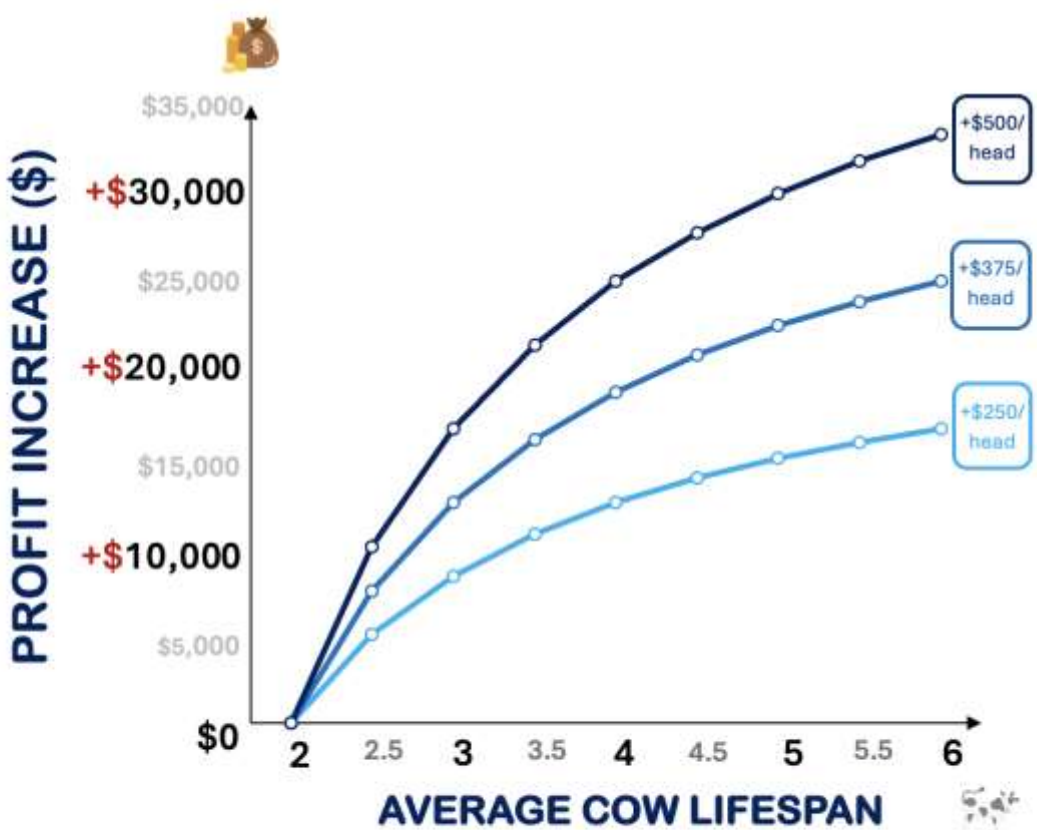
The model evaluates three key scenarios: the influence of lactation cycles, the use of sexed semen, and the effect of calving intervals on birth rates. The analysis is based on a representative US dairy farm with 100 cows (for simplicity), as the results can be linearly extrapolated. We make the following assumptions:

1. The cost of producing a crossbred calf is assumed to be identical to that of a purebred Holstein calf, allowing the model to focus solely on the incremental revenue generated by crossbreeding.
2. Each cow is expected to produce one calf in every lactation cycle, with a 50% heifer birth rate when using conventional (unsexed) semen.
3. The price premium between crossbred and purebred ranges between \$250 and \$500 per head, reflecting a more conservative markup than the values presented by Torres (2023).

Scenario 1: Extending the Herd Lactation Cycle

The first scenario explores how extending the average herd lactation cycle influences the profitability of crossbreeding (illustrated in Figure 2). We assume a range of 2–4 lactation cycles, which reflects the 4.5–6 year average lifespan of dairy cows (De Vries, 2020), in which cows first calve in their second year and stay in production for about 3–4.5 years (Pinedo et al., 2014).

Figure 2. Impact of Herd Lactation Cycle on the Profitability of Crossbreeding



To understand the results of the model, start by assuming that the average lactation cycle of the 100 dairy cows is only 2 years. This means that every year, 50 cows will be replaced with a heifer. Assuming a 50% chance of a heifer in a birth, the dairy operation would need all 100 lactating dairy cows to be mated with purebred dairy bulls to produce the 50-purebred female offsprings. This leaves no room for crossbreeding. This is reflected in the intercept of Figure 2.

Now, assume an average herd lactation period of 4 years; the dairy operation requires 25 replacement heifers annually (= 100 cows/4 lactations) to sustain its herd size. Given a 50% chance of producing a female offspring, only 50 dairy cows are necessary to generate the required heifer replacements. This leaves an additional 50 cows available for crossbreeding with beef bull semen, yielding 50 crossbred calves per year. If the price premium of a crossbred calf over a purebred dairy calf is $250, this breeding strategy would generate an additional $12,500 in annual revenue for the farm (Figure 2).

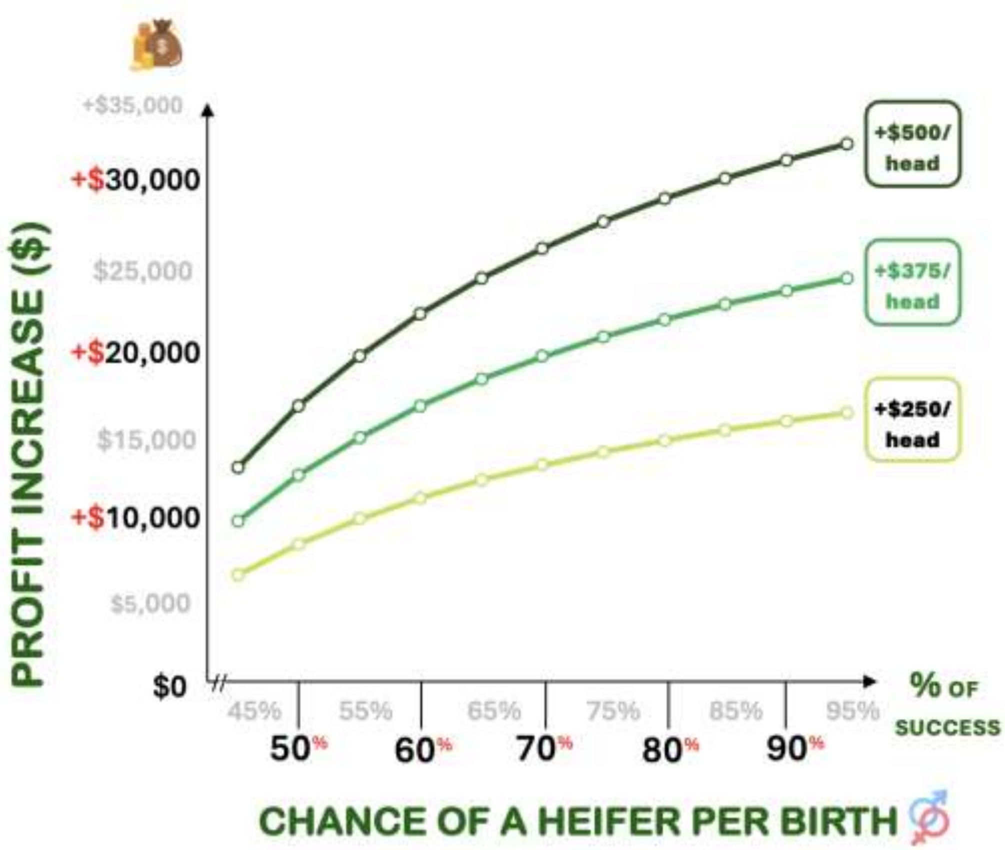
This means that extending the average lactation period allows for a greater proportion of the herd to be allocated to crossbreeding, thereby enhancing total farm revenue. Moreover, sensitivity analysis indicates that the financial benefits of this strategy increase with higher price differentials between purebred and crossbred calves.

Scenario 2: Use of Sexed Semen

In this scenario, we assess the financial implication of employing sexed semen on crossbreeding dairy cattle. Sexed semen is a reproductive biotechnology that enhances the probability of producing a female offspring (Hutchison and Bickhart, 2016). However, this method is generally more expensive and typically results in lower conception rates (chances of impregnating the cow) compared to conventional unsexed semen (Ettema et al., 2017).

For this example, let's assume an average of three lactations per cow (or 33.3% reproduction rate), which is consistent with industry patterns, and no differences in conception rate between insemination methods. We then vary the proportion of dairy of cows inseminated with sexed semen from purebred dairy bulls (Figure 3). We start with a lower bound of 45% success (birth) rate, which is slightly slower than the chances of producing a heifer using conventional insemination. Then, we increase the success rate up to 95% likelihood, which is the rate where almost all cows will produce a female offspring.

Figure 3. Impact of Using Sexed Semen on the Profitability of Crossbreeding



Using sexed semen to produce purebred heifers increases the availability of cows for crossbreeding with beef sires, thereby enhancing farm profitability through higher revenue from beef-on-dairy offspring. In our example, with a lactation cycle of 3 years, we need 33 purebred heifers. If the success rate is 75%, we need 44 cows to be inseminated with sexed semen. This leaves 56 dairy cows available for crossbreeding. When the price premium is $250, the profit is $14,000 (= $250/calf × 56 calves).

At low (45%) success rates, profits range from $6,500 to $13,000, whereas higher (95%) success rates raise profits to between $16,000 and $32,000, driven largely by the increased premium paid for crossbred calves. Thus, Figure 3 shows that increasing the success rate of the herd leads to substantial gains in profits, particularly when the price premium of crossbred calves exceeds that of purebreds.

However, it is important to note that this analysis does not incorporate the genetic gains from selectively breeding the healthiest and most productive cows (those with higher milk yields and fewer issues such as mastitis or calving difficulties), which could further enhance long-term herd performance and overall farm profitability.

Scenario 3: Longer Periods Between Lactations

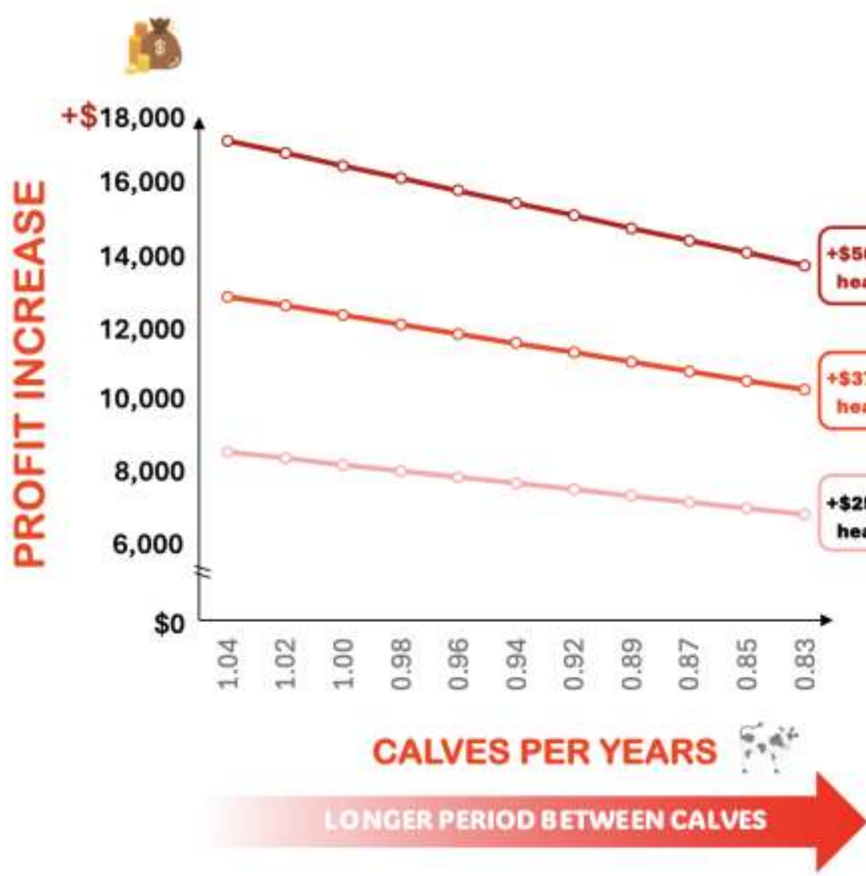
In this last scenario, we assess how performance (length of time between pregnancies) impacts farm profitability. We maintain our initial assumption that the average herd lactation cycle is 3 years. Regular semen is used, with a 50% probability of producing a heifer.

Calving intervals are varied from 11 to 14 months, corresponding to annual calving rates from 1.08 to 0.83 calves per cow (depicted in Figure 4). As the calving interval increases, the total number of calves produced per year declines, reducing the pool of animals available for either replacement or crossbreeding with beef sires. This reduction limits the potential for generating revenue from beef-on-dairy crossbred calves. The difference in annual revenue between cows with shorter versus longer intervals ranges between $180 and $70 per cow, which provides clear financial incentives to optimize reproductive efficiency.

Beef-on-Dairy Crossbreeding Impact on the Beef Sector

Crossbreeding beef sires' genetics on dairy cows improves the carcass traits and growth potential of the dairy bull calves, fetching higher prices in the beef

Figure 4. Impact of Longer Periods Between Lactations on the Profitability of Crossbreeding



market (Tsiligianni et al., 2024) and reducing dairy replacement costs (Buckley, Lopez-Villalobos, and Heins, 2014). Crossbred calves are well-suited to commercial beef systems and typically follow a consistent production pathway (Lynch, McGee, and Earley, 2019): (1) raised initially in cow-calf operations until weaning, which typically occurs at 10 weeks of age, (2) entering a backgrounding phase at a stocker operation where the animal is fed until achieving a certain weight, and (3) transitioned to a feedlot for 16–18 months (Berry, 2021).

On average, crossbred offsprings have higher calf-weaning rates (Fraga et al., 2016) and are over 46 kg heavier than purebred beef calves (Coleman et al., 2016), which could be attributed to heterosis (Fraga et al., 2016). The net effect depends greatly on the genetics of the sire. Research indicates that European breeds such as Charolais and Simmental produce heavier offspring when bred with beef-dairy cows compared to Angus-sired calves from the same cows (Coleman et al., 2016).

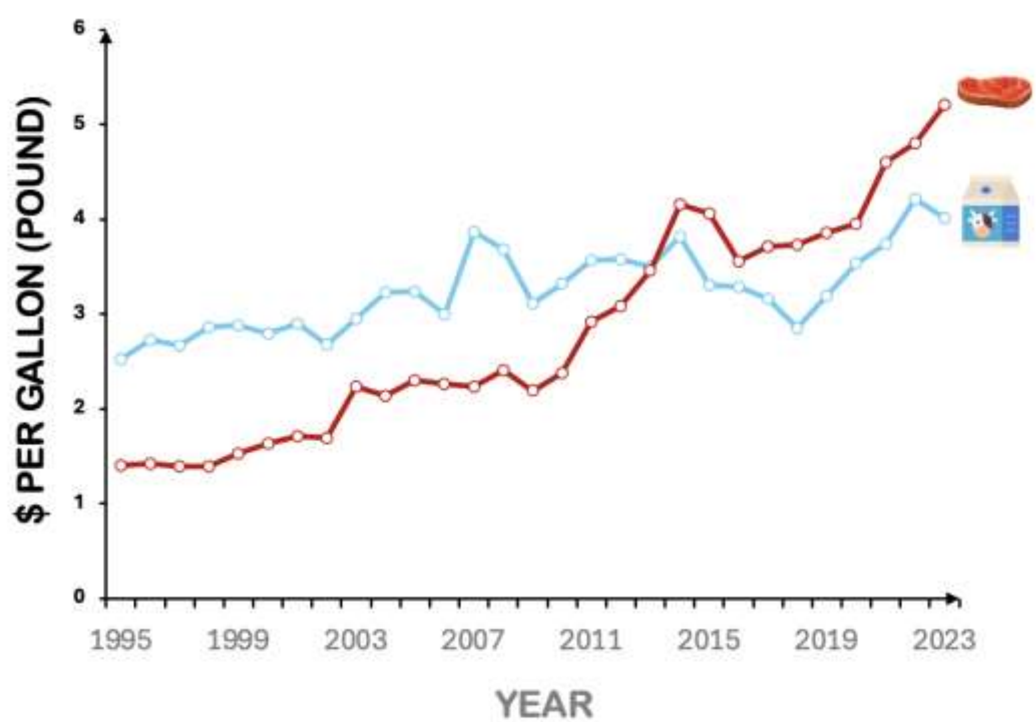
Integrating crossbred animals in cow-calf operations under proper management strategies have also been shown to lower their carbon emissions, fossil energy use, and water consumption (Baber et al., 2020). However, research shows no major differences in environmental impact per kilogram of carcass weight of producing beef-on-dairy animals compared to purebred beef (Berry, 2021). Thus, additional research is needed to understand the environmental impact of crossbred animals (Shiddieqy, Rofiq, and Widiawati, 2022).

Retail prices for fresh milk and ground beef in the United States have steadily risen since 1995, with ground beef surpassing milk in price by 2013 and maintaining that lead through 2023 (Figure 5). This growing beef price premium underscores the economic potential of crossbreeding beef sires with dairy cows. Raising a 500-pound steer incurs an estimated cost of $5.32 per pound, with an additional $750 in processing costs. Retail prices vary widely: Lower-end cuts like ground beef and chuck roast range from $2.77 to $7.99 per pound, while premium cuts such as New York strip and T-bone steaks command $8.48 to $11.81 per pound. On average, 30% of the carcass weight (150 lb) yields higher-value cuts, while the remaining 70% (350 lb) consists of lower-end products. By sourcing beef-on-dairy crossbred calves, beef producers benefit from a more uniform and higher-yielding animal compared to traditional dairy bull calves, improving feed efficiency, carcass quality, and overall profitability in the beef supply chain.

Conclusions

This study highlights the economic rationale for crossbreeding dairy cows with beef sires as a viable diversification strategy in US dairy farms. Given volatile milk prices, labor shortages, and rising disease threats, resilient operations must rely on alternative revenue

Figure 5. US Retail Prices of Milk and Meat



streams. Our decision-tree model shows that strategic use of reproductive tools, such as sexed semen and shorter lactation cycles, can improve the financial benefits of crossbreeding. Shorter lactation cycles lead to greater capacity for crossbreeding part of the herd. Use of sexed semen increases the likelihood of a purebred heifer being born, and thus greater availability of surplus cows to be crossbred with beef sires. Finally, the length of periods between calving adversely affects the returns from crossbreeding. Thus, the replacement rate of the dairy herd is of primary concern. Crossbreeding beef-on-dairy makes sense if the herd produces surplus heifers.

While financial gains are driven by the premium prices of beef-on-dairy calves, the benefit extends beyond the dairy sector. Beef producers receiving crossbred calves gain access to more uniform, heavier-yielding animals that perform better in feedlot and processing stages. Thus, beef-on-dairy systems enhance overall supply chain efficiency. Future research should further assess the genetic, environmental, and market dynamics to optimize integration and sustainability across dairy and beef systems.

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Changes to Milk Pricing Formulas Under Federal Milk Marketing Orders Will Affect Farm Milk Prices

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After a lengthy administrative process to evaluate the evidence about the need for pricing changes that began in March 2023, the Dairy Division of the USDA released a final decision in mid-November 2024 detailing changes to milk pricing under Federal Milk Marketing Orders (FMMO). In the subsequent producer referendum in December 2024 and January 2025, these changes were approved for all 11 current FMMOs, and new pricing formulas became effective in June 2025. These changes are the most substantive in more than 2 decades and include many modifications to formulas affecting minimum regulated milk prices. This article summarizes the changes and assesses their potential impacts on milk prices through 2028. A review of FMMO pricing sets the context for the upcoming modifications.

Minimum Regulated Farm Milk Prices Under FMMOs

FMMOs set minimum regulated prices paid to producers (and cooperatives) and pool the revenues from those prices to generate a weighted-average producer price (a blend price). The changes implemented in June 2025 affect pricing, not pooling. Minimum regulated prices are based on product price formulas that determine an implied value for farm milk based on the products made from it. FMMOs survey wholesale dairy product prices for butter, cheddar cheese, dry whey, and nonfat dry milk and use formulas to calculate the value of four components in farm milk (butterfat, protein, nonfat solids, and other solids). The values of these components determine the minimum regulated prices paid for farm milk, based on the use of the milk, or its class. The formulas also account for the yield of product; for example, about 1.2 lb of butter can be made from a pound of butterfat because commercial butter contains only 82% butterfat plus water and salt. Product price formulas also account for the cost of transforming farm milk into the surveyed products, a dollar value per pound that is known as a *make allowance*. A typical calculation for a component value would thus be specified as

Component price = (Wholesale product price – Make allowance) × Yield factor,

where the component price is measured in $/lb of component (like butterfat), the wholesale product price and make allowance are measured in $/lb of product (like butter), and the yield factor is measured in pounds of product (butter) per pound of component (butterfat).

The current FMMO system sets minimum prices for four classes each month based on the product into which farm milk is made: Class I (beverage products), Class II (soft products like yogurt and ice cream), Class III (cheese and whey products), and Class IV (other products such as butter and milk powders). FMMOs focus on the policy goal of maintaining a sufficient supply of farm milk available for beverage use (that is, for use in Class I). Achieving this implies there is “orderly marketing” of farm milk for beverage use. (This term is contained in the original authorizing legislation for FMMOs but is not precisely defined.) As a result, Class I prices are set differently than prices for the other classes. First, Class I prices are set in advance of the month to which they apply; other class prices are calculated after the month is completed. Class I prices depend on the values of Class III and Class IV skim milk prices (currently based on their average plus $0.74/cwt). The Class I price also includes a location-specific “differential” that reflects the extra cost of servicing the fluid milk market and regional supply, demand, and transportation considerations. Thus, Class I milk often has the highest of the four class prices. Finally, payment of minimum prices for Class I milk by fluid milk processors is mandated in FMMOs, but the buyers of farm milk for other uses may opt out of minimum price regulation. Other classes of milk will typically agree to pay minimum regulated prices when they will share in the value of the “pool” of dollars that includes the higher value for milk used in Class I.

Minimum class prices are computed and reported by USDA based on component values assuming

Table 1. Summary of Changes to Milk Pricing Formulas in the Final Decision

Element of Pricing Formula	Previous Formulas	Change with Final Decision
Make allowances	Values specified for four products, ranging from about $0.17/lb for dry whey to $0.20/lb for cheese	Increases in make allowances for all products from $0.05/lb to $0.07/lb
Yield factor	The recovery of butterfat in cheese is assumed to by 90%, resulting in a yield factor of 1.572	Increase in the recovery factor to 91%, resulting in a yield factor in cheese of 1.589
Skim milk composition factors	Composition to calculate skim milk values for class prices uses 3.1% protein, 5.9% other solids or 9.0% other solids	Increases the value to 3.3% protein, 6.0% other solids or 9.3% nonfat solids
Surveyed products	Includes block and barrel forms of cheddar cheese in surveyed products to determine component values for Class III prices	Removes barrels from the prices used to set component values for Class III prices
Class I skim milk price	Currently set as the average of the Class III and Class IV Skim Milk prices plus $0.74/cwt	Uses the higher of Class III Skim Milk and Class IV Skim Milk (this formula was in place until changed in 2019)
Class I differentials	Values for each of 3,108 US counties, ranging from $1.60/cwt to $6.00/cwt, with highest values in the Southeast	Increase the values in each of 3,108 US counties between $0.05/cwt to $2.40/cwt, with the largest increases in the Mid-Atlantic and West Virginia
Pricing of extended shelf life milk in Class I	Priced as Class I milk without adjustment	Adjustment to the Class I price equal to the difference between the higher of and average of plus a 24-month rolling adjuster with a 12-month lag

standardized milk composition values of 3.5% butterfat and 96.5% skim milk. However, the actual minimum regulated value for milk varies in the 11 different FMMO marketing areas. In *Multiple-Component Orders*, the minimum value is based on the value of protein and butterfat in farm milk at Class III values, with the remaining weighted average revenues distributed as a Producer Price Differential (PPD). In *Skim-Fat Orders*, producers are paid based on the value of fat and skim milk solids.

Changes will be made to many elements of these pricing formulas, including which wholesale product prices are surveyed, the make allowances, a change to one of the yield factors, the assumed standard milk component composition, how advanced Class I skim prices are determined, how extended shelf-life milk will be priced, and the Class I location differentials (Table 1).

Changes in the Final Decision

Changes to Make Allowances

As noted earlier, the desire to change (increase) make allowances was a major motivation for the hearing, and the final decision increased these between 5.2 and 7.1 cents (Table 2). In relative terms, the increases are 26%–42% higher than the existing make allowances. Proposals to increase the make allowances were supported by many major dairy organizations, including those representing both dairy farmers and dairy manufacturing companies. The specific values proposed and the implementation timelines differed for these organizations, and some proposals included methods for automatic adjustments in the future. (Make allowances were last adjusted in 2008, and this was an attempt to ensure they would be adjusted more regularly in the future.)

Table 2. Current and Final Decision Product Make Allowances, $/lb Product

Product	Previous	Final Decision	Change
Cheese	0.2003	0.2519	0.0516
Dry whey	0.1991	0.2668	0.0677
Nonfat dry milk	0.1678	0.2393	0.0715
Butter	0.1715	0.2272	0.0557

Make allowances that are lower than the actual costs of transforming milk into products for a large number of manufacturers would make it difficult for those manufacturers to pay the minimum regulated class prices for milk (or any price premiums above them). Thus, they also provide an incentive to de-pool (opt out of the regulated pricing system) to avoid having to pay the minimum prices. Make allowances lower than actual costs could also discourage investment in new processing facilities unless the new facilities could achieve costs lower than the current make allowance values. Based on the generic pricing formula indicated above, an increase in the make allowance will result, for a given product price, in a reduction in the milk component values because a larger value is subtracted. This would lead to lower minimum regulated milk prices, at least in the short term.

Changes to Milk Composition Factors

Milk composition factors represent the protein, other solids and resulting nonfat solids in skim milk. These composition factors affect the prices of Class III and Class IV skim milk, which in turn affect the reported Class III and Class IV prices and the Class I price. USDA specified increases the protein composition, the other solids composition (used in pricing Class III skim milk), and the nonfat solids composition (used in pricing Class IV milk) (Table 3).

This increase is in response to proposals to have base prices reflect current milk composition. All milk component levels in farm milk—butterfat, protein and other solids—have increased since the last update in 2000. Component levels are increasing because of economic incentives provided by component-based prices, facilitated by improved genetics and nutrition. Increases in the composition factors will increase Class III and Class IV skim milk prices and, therefore, have a positive impact on the Class I skim milk price. Proponents of changes to composition factors indicated that these changes would increase the Class I skim milk price by $0.60/cwt to $0.70/cwt, which would promote "orderly marketing" by encouraging movement to Class I uses.

Changes to Surveyed Commodity Products

Class III prices are for milk used in cheese with dry whey as a co-product. To determine cheese prices, wholesale cheddar prices are surveyed using a weighted average of 40-lb blocks and 500-lb barrels (with an adjustment for the moisture content). The final decision removes 500-lb barrel cheddar cheese from the surveyed dairy products.

Testimony in favor of dropping barrels asserted that the spread between barrels and block prices has become volatile—rarely near the assumed $0.03/lb value in the current formulas. Dropping barrel cheese from the price calculations could create more orderly marketing conditions by reducing uncertainty for dairy farmers and manufacturers. It was also noted in favor of this change that the spot market CME block cheddar cheese price is used to price 90% of the natural cheese produced in the United States.

Changes to the Base Class I Skim Milk Price

The Class I skim milk price (part of the Class I price) is currently calculated as the average of the Class III and Class IV advanced skim milk price plus $0.74/cwt.[1] This method was introduced in May 2019. Prior to that change, the Class I skim milk price was calculated as the higher of the Class III and Class IV advanced skim milk price. June 2025 will see a return to return to the higher of Class III or Class IV skim milk price for determining the Class I price. Testimony in favor of returning to the higher of the two prices noted that this method tends to maintain Class I as the highest-priced class and reduce milk price variation. However, concerns were raised in other testimony that the primary motivation to change from the higher of the two prices to the average was to provide certainty for milk processors about their raw milk costs and to facilitate risk management. In addition to the return to the higher of Class III and Class IV skim milk for pricing Class I, the USDA also specified alternative pricing for Extended Shelf Life (ESL) milk, which is "longer lasting" and does not spoil as quickly as fresh milk. The longer shelf life means it can be marketed and transported differently than shorter shelf life, non-ESL milk. Changes for ESL milk included an adjustment to the Class I price equal to the difference between the higher of and average of plus a 24-month rolling adjuster with a 12-month lag. This change largely affects the timing of the payments to Class I, not the overall value of Class I milk.

Table 3. Current and Final Decision Skim Milk Composition Factors, %

Component	Current	Final Decision
Protein	3.1	3.3
Other solids	5.9	6.0
Nonfat solids	9.0	9.3

[1] Recall that the minimum regulated Class I milk price is set in advance of the month in which milk will be purchased. For that reason, Class I prices used "advanced" component values based on surveyed product prices. The process is similar to that for pricing components used in other classes, but the timing differs.

Table 4. Summary of Changes in Class Prices for December 2024 with the Final Decision Compared to Current Price Formulas

Milk or Component Value	Impact of the Changes in Make Allowances	Comment
Class I price (reported value at national average value of Class I differential), $/cwt	0.52	Includes effects of changes to make allowances for Class III and IV, changes to Class I Differentials and "higher of" pricing
Class III price (reported value), $/cwt	−0.53	Includes changes to make allowances and composition
Class III butterfat price, $/lb	−0.0675	Lower butterfat price for same butter price
Class III protein price, $/lb	−0.0985	Lower protein price for the same cheese price
Class III other solids price, $/lb	−0.0697	Lower other solids price for the same dry whey price
Class III components (pool value at component test), $/cwt	−1.05	Component values at average farm milk composition (Upper Midwest order)
Class IV price (reported value), $/cwt	−0.52	Includes changes to make allowances and composition
Class IV butterfat price, $/lb	−0.0675	Lower butterfat price for same butter price
Class IV nonfat solids price, $/lb	−0.0708	Lower nonfat solids price for the same nonfat dry milk price
Class IV components (pool value at component test), $/cwt	−0.95	Component values at average farm milk composition (Upper Midwest order)
Milk not currently pooled	Not known	Could increase if premiums return or milk is pooled
Milk currently pooled by a cooperative but with re-blending (deducts)	Not known	May not change very much if current pay prices account for cooperative costs

Changes to Class I Differential

Class I differentials are specified for each US county where farm milk is first received for processing. The values of Class I differentials will be increased by up to $2.40/cwt in areas of the Southeast, with an average nationwide increase of $1.24/cwt, but maintain the current minimum value of $1.60/cwt. Organizations representing dairy farmers proposed increasing Class I differentials to address increases in milk hauling costs, changes in milk supply and demand locations, changes in supply patterns resulting in longer hauls, and insufficient price premiums to cover the cost of servicing Class I markets. Class I differentials outside of the Southeast had not been updated since 2000. Testimony based on a large-scale spatial economic model provided information about how milk values in Class I had changed over time due to changes in milk supply, product demand, transportation costs, and the location and capacity of fluid milk processing plants.

Impacts of Formula Changes on Minimum Regulated Milk Prices

Although the USDA's primary responsibility is to ensure "orderly marketing" of milk for use in Class I, an outcome of broad interest to US dairy farmers is the impact of these changes on classified milk prices, the weighted-average (blend) price in different parts of the United States, and actual prices received. The USDA's regulatory economic impact assessment (USDA, 2024) of the changes reported the impact on weighted-average prices at standard composition and actual composition ("at test") for each of 11 milk marketing orders based on amounts of milk in the four classes using data from 2019 to 2023. Those analyses indicated that the overall effects of the changes on these prices would be positive, although negative for the Upper Midwest, California, and Arizona orders.

Illustrative Changes to Classified Prices

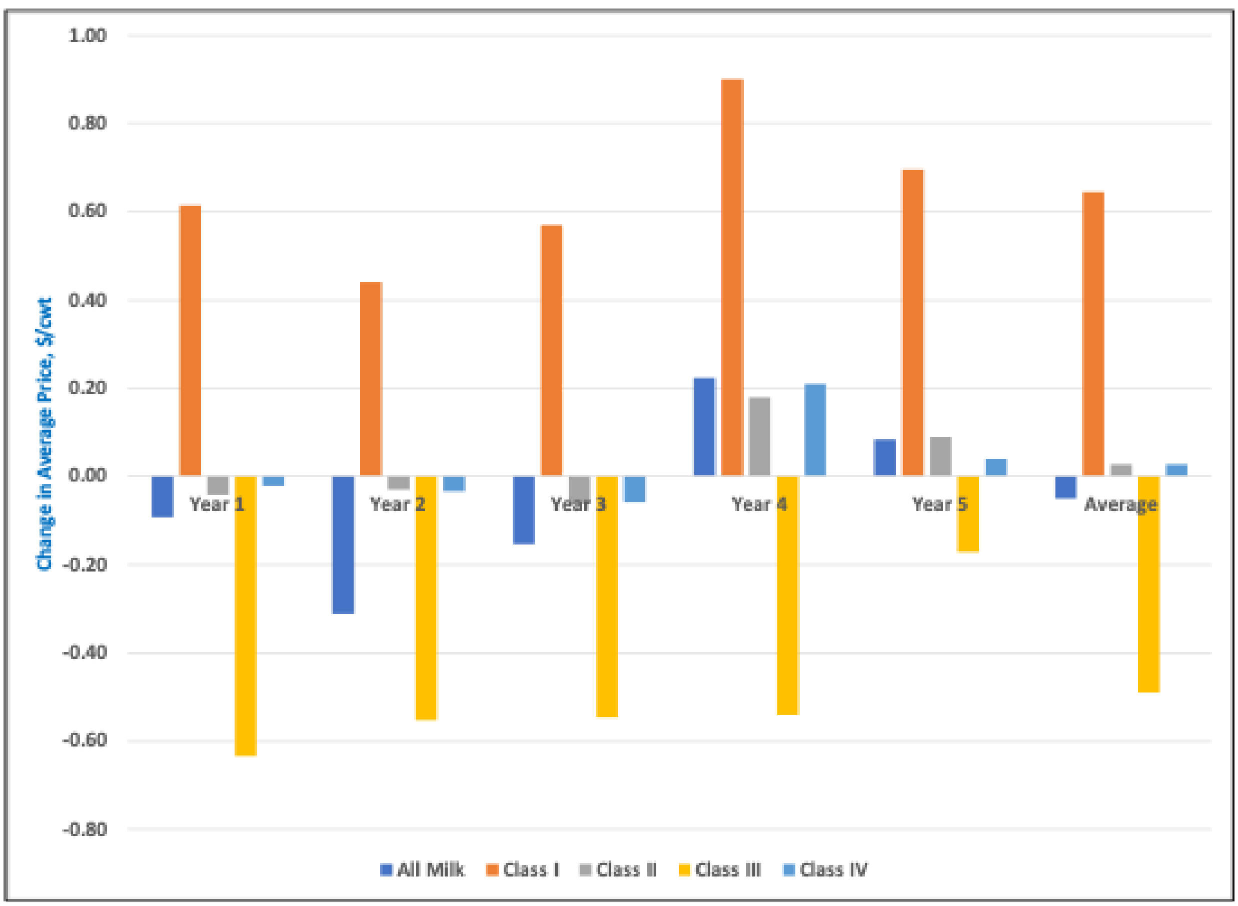
To illustrate the types of changes in classified milk prices implied by the modifications to pricing formulas, it is useful to consider an example for 1 month. If the changes in make allowances and yield factors were implemented with the product prices observed in December 2024, they would have resulted in a Class III price −$0.53/cwt lower than with current formulas (Table 4) and a Class IV price about −$0.52/cwt lower. Class I values for this month would have been $0.52/cwt higher, with the new pricing formulas due to increases in the Class I differentials, although offset to some extent by the lower Class III and Class IV skim milk values used in the calculation (due to make allowance changes). However, many dairy producers are paid based on the quantity of components; at the average component content of farm milk in the Upper Midwest order, the value of components used in Class III would be lower by $1.05/cwt.

However, impacts on component values and reported class prices may not always reflect the likely impact on farm milk prices. Farms pooling milk and receiving the full regulated minimum Class III price would see reductions in component values ranging from about $0.07/lb for butterfat to $0.10/lb for protein (Table 4). However, not all milk is pooled, and some pooled milk may receive less than the minimum regulated price due to deductions by cooperatives. For those farms, any price decreases will likely be smaller than those based on reported prices or component values—and pay prices for some producers could actually be higher. Similarly, impacts on Class I prices will vary by order. For example, increases in Class I differential values are similar in the Upper Midwest, Mideast, and Florida orders, but the impact on farm milk prices will be larger in Florida due to a higher proportion of Class I milk.

Dynamic Assessment on Milk Prices of the Changes to Price Formulas

Our example of price impacts above is one common approach to evaluating the impacts of changes: Use historical data on product prices and modify make allowances and yield factors to calculate a new series of class prices. The USDA's approach used observed historical quantities of milk and components pooled by order and then adjusted the monetary value of those quantities to reflect changes to the value of components based on modified pricing formulas. Although frequently

Figure 1. Simulated Differences in Class Prices and the US All Milk Price After Implementation of Changes to Pricing Formulas, Accounting for Change to the Supply and Demand Balance for Milk



used, these approaches are limited in that they do not account for how changes in the farm milk price due to changes in the formulas will affect milk production, its allocation to different uses, and product prices. In essence, both are static historical approaches that assume total milk production, allocation, and product prices will remain unchanged even as farm milk prices are changed. Thus, although helpful as a first approximation, historical static analyses can be complemented by a forward-looking, dynamic analysis that accounts for the potential effects of farm milk prices on milk production and allocation and thus also product prices that are used in the pricing formulas.

The changes to the formulas imply lower values for components and minimum regulated prices for milk used in manufacturing for given values of wholesale product prices (for butter, cheese, dry whey, and nonfat dry milk). However, these product prices are likely to be affected in the future by changes to the production of, and demand for, farm milk given the changes to the pricing formulas. We would expect that any reduction in component values and farm milk prices will result in different production decisions by dairy farms (less milk and components produced) and purchase decisions by dairy plants (more milk and components purchased). Thus, the farm milk prices beginning in June will affect future production and the demand for farm milk. Dynamic economic modeling (Nicholson and Stephenson, 2024) of these potential impacts indicates that any initial price decreases will result in somewhat lower milk production in the next couple of years, which in the future will affect the supply-demand balance for farm milk and mitigate some impacts of the changes that began in June (Figure 1). We project that over the next five years, the impact on the average All Milk price in the US will be about $0.07/cwt lower than it would have been without the changes (including estimated changes to over-order premium payments).

Summary

The USDA’s final decision, which was approved for all 11 FMMOs through a producer referendum early in 2025, represents the most substantive changes to milk pricing regulation under FMMOs in nearly 20 years, with important implications for dairy producers, processors and consumers. These changes will affect farm and dairy manufacturer profitability and consumer demand for years to come.

For More Information

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